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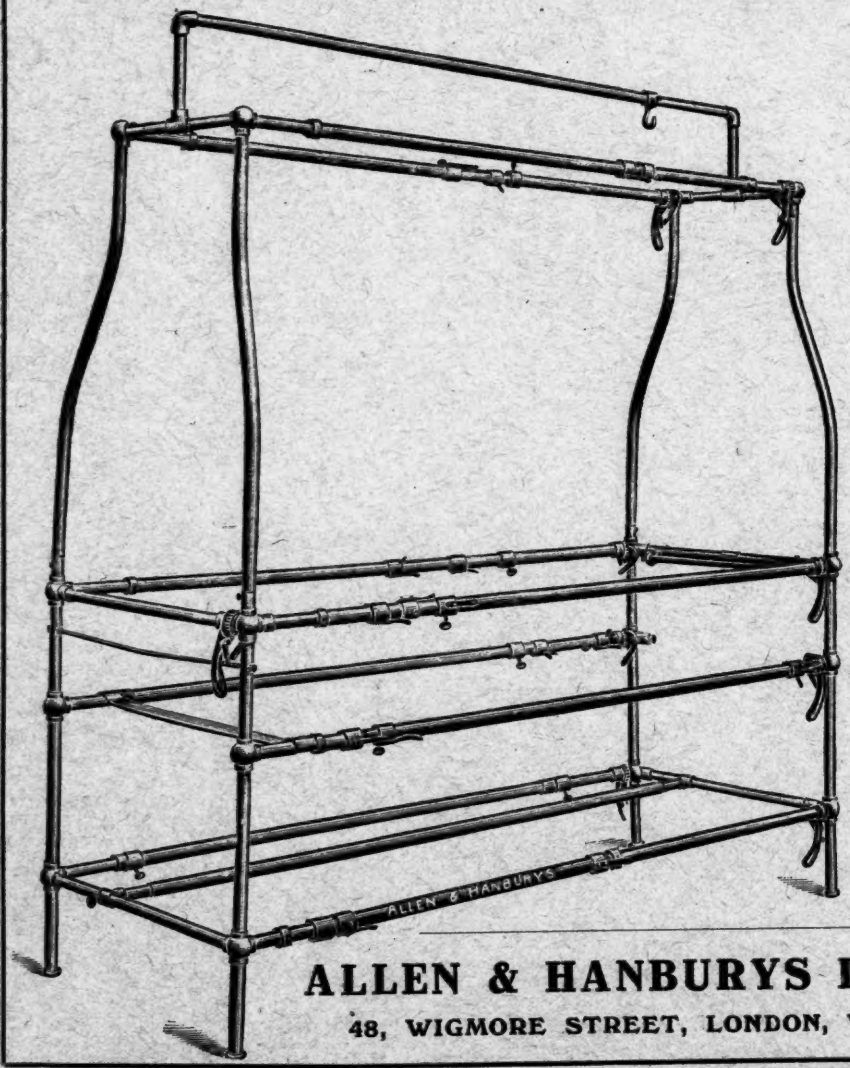

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THE
BRITISH JOURNAL OF SURGERY

INTRODUCTORY.

SCATTERED in many museums of pathology there are specimens illustrating injuries incurred in warfare. Some of them date from the Napoleonic wars, especially the Peninsular campaign and Waterloo. Few of the specimens do much to illustrate pathology, and most of them may be regarded as mementoes, or as curious examples of the vagaries of missiles. Some are interesting inasmuch as they recall the names of famous military surgeons. Specimens from the Crimean war and the Franco-German war are mainly macerated bones showing fractures produced by bullets. Even from the South African campaign, such soft specimens as are available were obtained by personal effort; no systematic effort was made by the Medical Department of the Army to secure preparations for illustrating injuries of the human body caused by the destructive weapons used in modern warfare, and to prepare and arrange them for reference and study.

In 1914 a Committee was appointed to compile a Medical History of the Great War, and this Committee soon appreciated the importance of obtaining specimens demonstrating the effects of modern projectiles on the bodies of men, and of having such specimens prepared, suitably preserved, and catalogued. The official facts regarding this matter are described by Professor Arthur Keith in the preceding volume. In this introductory note it is proposed to emphasize the chief features of the pathological side of the Collection, its aims, and the lines along which it may be usefully extended.

In preparing the specimens, great care has been taken to preserve the injured parts in their anatomical surroundings; instead of dissecting out a damaged artery or vein, and slitting it up to show the rent made by a missile in its wall, the region is dissected and preserved, whenever possible. Some of these 'regions,' dissected with great skill and care by Cecil Beadles, may be described as works of art.

Moreover, the old method of preserving the specimens in alcohol has been abandoned, solutions of formalin, and glycerin, being freely used. These liquids have been on trial at the Royal College of Surgeons for a sufficient length of time to justify the opinion that they are superior to the old spirit-and-water method.

It is proper to mention that much of the success of the wet specimens is due to the careful pickling they received from the officers at the various military hospitals in France. Instructions in regard to the preliminary treatment of the parts were circulated, and they have been so thoroughly followed that the majority of the specimens reached the College in good condition.

It is an interesting feature of the Collection that many of the communications that have appeared already in this and other medical journals concerning gunshot injuries incurred in the Great War, relate to specimens belonging to it; thus the Collection may not inaptly be regarded as a Pathological Record Office.

Later, when the Medical History Committee publishes its Report on the War, the evidence of many of the cases will be available in a concrete form in the Museum.

To the military surgeon these excellent preparations of injured organs, carefully

catalogued and described, with the chief facts of their clinical histories, will be used by authors as type specimens in the same way that zoologists, botanists, and geologists use the contents of the Natural History Museum when they wish to compare new species, or suspected new species, of plants, fishes, reptiles, birds, or beasts that live on the earth, or the fossilized remains of those that formerly moved about the earth or inhabited its waters.

In collecting material useful for illustrating gunshot wounds, some of us desired to obtain specimens from the battlefield in which projectiles induced instantaneous death. This can only happen in two situations—the head and the heart. In the early stages of the war there was some fear that, without special effort, only specimens obtained from patients admitted to the hospitals would be available for museum purposes. Thanks to the zeal of the medical officers in France, especially Lieutenant-Colonel T. R. Elliott, some instructive specimens have been preserved. So remarkable are the effects produced by a bullet of high velocity traversing the Head of a living person, that the skull is often burst as by an explosion. The most characteristic effects are produced when a bullet enters the forehead and escapes by the occiput, or *vice versa*. The bullet enters by a neat round hole, but the bone in the neighbourhood of the hole by which it escapes is broken into fragments ; indeed, the cranial wall is broken and cracked like a pane of glass shattered by a stone. A critical examination of the macerated skull shows that the lines of sutures are often 'started,' and occasionally opened. This indicates that the intracranial pressure imparted by a bullet traversing the brain with a high velocity must be enormous. This is not a peculiarity of the elongated and pointed bullets used in the British, French, and German armies. Similar effects were recognized in the case of the Snider rifle-ball. Kipling expresses this in his well-known verses on "The Grave of the Hundred Head" :—

"A Snider squibbed in the jungle—
Somebody laughed and fled,
And the men of the First Shikaris
Picked up their Subaltern dead,
With a big blue mark in his forehead
And the back blown out of his head."

The physical disturbance engendered by a bullet traversing the brain, or any hollow organ filled with fluid or viscous material, must be very great. In the case of the brain it leads to instant paralysis : circulation and respiration are completely stopped.

Instantaneous death from a high-velocity bullet traversing the head is a marked contrast to the long-drawn-out helplessness that ensues when a soldier has his back broken by a bullet. Examples of gunshot wounds of the Spine are numerous in the Collection. They are most depressing specimens ; they recall the long-suffering wounded soldier whose existence can only be described as a living death. An analogous condition can be studied in the insect world. The inimitable observer, Fabre, has described the fiendish method employed by a digger-wasp, *Sphex*, for provisioning the brood-chambers with crickets. This wasp paralyzes crickets by stinging them in the nerve ganglia. *Sphex* then deposits an egg on the ventral surface of its paralyzed victim. The larva, hatching out in a few days, eats and thrives on the soft tissues of the helpless cricket.

A soldier with his spinal cord damaged lies like a paralyzed cricket, living, but unable to move, and conscious of his helplessness. The hole by which the bullet entered his spinal canal admits pathogenic and saprophytic micro-organisms to prey, and flourish, on his tissues like the larvæ of the fossorial wasps on helpless crickets. There is no class of gunshot wound that entails more mental misery than gunshot wounds of the spine, and few in which the resources of surgery and bacteriology are so helpless to cure or relieve, and none that excites so much compassion.

In the case of the Heart, when traversed by a high-velocity bullet, death is usually instantaneous, the dynamic disturbance causing it to stand still. Failing an instant paralysis, the wounded heart bleeds so freely and rapidly that death occurs in a few

minutes. In big-game shooting it occasionally happens that a large beast is brought to the ground by a broken back. When such an animal is deliberately finished by a bullet sent through its chest, either fore and aft, or from side to side, it dies instantly. On opening the chest, the heart will be found firmly contracted, and often there is no effusion of blood, either in the cavity of the pericardium or of the pleura. The effects of a sword plunged into the heart may be watched in the bull-ring. When the matador thrusts the weapon directly into the heart, the bull sinks instantly on the floor of the ring; but when the sword wounds the big vessels at the base of the heart, the bull may move about for many seconds whilst the blood escapes.

In previous wars little attention was given to gunshot wounds of the heart: they have been regarded as nearly always fatal. Indian sportsmen have often drawn attention to the fact that a tiger, shot in the heart, has had the strength to run for many yards before falling dead. Some of the hearts in the Collection show the destructive effects which modern missiles exert upon the thick walls of the ventricles. One heart, extensively lacerated near the apex by an armour-piercing bullet, merits attention. It belonged to an officer who was hit when flying over the German lines. He brought the aeroplane to earth in his own lines, but was dead when removed from the machine.

Farina, in 1896, proved that wounds of the heart are amenable to surgery; and his example influenced the treatment of such wounds during the Great War: there are specimens illustrating surgical enterprise in this direction. But the surprise of the Collection is a series of specimens indicating the methods and routes by which missiles reach the cavities of the heart; they prove that missiles occasionally enter the cardiac cavities by directly penetrating the walls of the heart, or arrive as flotsam and jetsam in the blood-stream. The evidence supplied by the specimens shows that fragments of metal, and entire bullets—shrapnel and rifle—penetrate large veins, such as the pulmonary, iliac, hepatic, and caval, and are transported as emboli to the heart. Some of the missiles, after reaching the auricular or ventricular cavities, have been retained. A few, embedded in clot, have been discovered post mortem. In several instances bullets have been detected radioscopically in the heart cavities during life, and their swirlings and gyrations in the blood-current, during systole and diastole, have been watched with the same interest that astronomical observers bestow on minor planets.

In some instances, bullets round and conoidal, or irregular fragments of metal, after reaching the cavity of a ventricle, are discharged and become dangerous emboli. There are specimens in the Collection, exquisitely prepared and displayed, showing metallic emboli impacted in the pulmonary artery producing infarction of the lung. Others, lodged in the iliac arteries, caused ischæmia of the lower limb.

The series of hearts showing the effects of gunshot wounds is probably unique, and if surgeons who have specimens with clinical histories would give them to this Collection they would add to its interest, and its value for teaching and for reference.

Even more remarkable are the specimens proving that bullets may penetrate large blood-vessels, like the aorta, and become centrifugal emboli, being propelled by the arterial current, or slip along the vessels by their own weight, until they become impacted in the common or the external iliac artery. These extraordinary events and sequences are not only represented by specimens, but complete clinical histories are available; the names of the officers who made the observations and carried out the treatment are duly recorded.

In a few cases the missiles within the chambers of the heart came as a post-mortem surprise, but in many instances the nature of the embolus has been recognized during life; in one instance a missile was observed in the heart radioscopically, and a few hours later it was detected by the same method in the common iliac artery (O'Neill). The parts belonging to this remarkable case are preserved in the Museum.

Few specimens illustrating gunshot wounds of the Viscera have been obtained in previous wars. In spite of the enormous development of abdominal surgery during the last thirty years, attempts to apply surgical measures to the treatment of gunshot wounds of the gastro-intestinal tract during the South African War were discouraged. In the early

period of the Great War few gunshot wounds of the intestine were submitted to operation. Many soldiers, shot in the lower abdomen, die in a few hours from hæmorrhage in consequence of wounds of the large vessels in the mesentery. Many who survive the bleeding die a few days later from sepsis due to leakage from perforations in the gut. Some surgeons believed that the modern elongated bullet produced a small hole in the intestine, and this accounted for the occasional recovery of men shot in the belly, under expectant treatment. An examination of the wounded segments of small intestine in the Collection, showing mucous membrane everted and protruding from the bullet-holes like the corolla of a full-blown flower, will quickly dispel such an illusion. There are some instructive examples of the surgeon's skill in dealing with wounded intestine. Many reports have been published in which officers, operating often in circumstances requiring courage as well as dexterity and resourcefulness, have succeeded in saving the lives of wounded soldiers in apparently desperate circumstances.

Coils of ileum showing multiple bullet wounds demonstrate that one of the problems facing the surgeon is choice of method. Is it better, in such injuries, to resect several feet of intestine, or patiently close the shot-holes with sutures? Some surgeons believe that the resection of a portion of small intestine for gunshot injury is often followed by recovery, but that double resections are attended with a high mortality. If those who have been occupied with this class of surgery in France would publish their observations it would help to guide surgical opinion on this important matter. Such a question could not be properly answered by a study of wounded intestines in a museum.

It is reasonable to believe that a soldier is more likely to recover after the removal of six inches than after the loss of six feet of gut. More than one case is known in which recovery has followed the resection of two yards of ileum. A notable specimen is a coil of small intestine, six feet long, with twenty perforations. In some parts the gut is so damaged that two-thirds of its circumference is torn through. This piece of ileum was excised by Owen Richards from a Scotch Canadian. The soldier after receiving this injury in a German trench, walked back to his own lines "because he wished to die among friends." He recovered.

The first specimen received at the College of Surgeons for the Collection was a piece of intestine, four and a half feet long, perforated in two places. The appendix was also perforated near its base. This piece of gut and the appendix were excised by Owen Richards.

The point of entry of a missile into a belly is no guide to the damage inflicted on the viscera. For example: a bullet entered the belly of an officer five centimetres above the highest point of the left iliac crest; passed through the transverse mesocolon, stomach (two places entry and exit), and the diaphragm; it then entered the right ventricle of the heart and perforated a flap of the tricuspid valve. It was expelled as an embolus into the right pulmonary vein. The officer died eleven and a half hours after being hit (Fullerton). We may compare with this a vermiform appendix (637). A soldier was hit in the flank. The appendix was perforated by the bullet, no other organ in the abdomen being injured. No details of the operation are available, but there is this laconic official statement—"Patient evacuated to base."

An instructive specimen is a Meckel's diverticulum with two perforations. A soldier was hit by a piece of shell in the right buttock; the missile passed into the belly by the side of the rectum, and made sixteen holes in the ileum, two holes in the diverticulum, and several holes in the mesentery. It was necessary to resect three and a half feet of ileum. The soldier recovered (Gordon Taylor).

When a soldier, wounded in the buttock, complains of intense pain in the belly, the surgeon, finding a wound in the buttock and none in the belly-wall, is apt to overlook the serious nature of the injury.

Even those who regard a museum mainly as a repository of curiosities will find these pathological specimens interesting. Bullets attain more curious positions by accident than they could obtain by design. This has been a subject of perennial interest since the

invention of firearms. The classical instances are bullets embedded in the solid portions of the tusks of elephants. The Odontological Section of the Hunterian Museum contains some admirable specimens of this kind. The mode by which metallic bodies, and even spear-heads, become encysted by secondary dentine, is almost as fascinating as the ways by which bullets reach the cavities of the heart of Man. Each in turn demonstrates the importance of scientific studies in explaining such apparently mysterious occurrences.

The manner of the encystment of missiles in tissues shows that when metallic bodies are germ-free—sterile,—apart from the injury inflicted when traversing the tissues they lead to little inconvenience ; but a fragment of metal soiled with mud, or a piece of germ-laden skin entering the head, trunk, or limb of a living person, may be as lethal as a cobra bite. A small piece of metal may pierce a man's forehead and sink an inch or more into his brain ; this does not necessarily lead to death ; but a similar fragment of metal entering the back of his head and carrying some dirty hairs from the scalp to the inner side of the dura mater will almost certainly lead to fatal meningitis. Surgeons were long in learning this simple lesson.

The same important truth may be learned in any part of the body. A soldier may have a portion of a digit carried off by a bullet and die from septic infection. Another may have his lower abdomen traversed by a bullet, and recover after a temporary indisposition. The size of a missile is no guide to its killing powers. The nose-piece of a shell as big as a duck's egg has lodged in a man's buttock and done little harm, but a ragged piece of metal a centimetre in diameter has broached the aorta, or the vena cava, with rapidly fatal consequence from bleeding. A 7-mm. revolver bullet has passed through the superior mediastinum of a man and lodged under the vertebral border of the left scapula, and caused merely a blood-stained pleural effusion from which the man speedily recovered.

Strange things which have been converted into missiles by the impact of projectiles are sometimes found in soldiers. The impact of a high-velocity bullet against a button on a soldier's tunic sent it forward with such force against a guardsman's face that it became embedded in his upper jaw. The radioscopic appearances were puzzling ; and the surgeon was astonished when he extracted the missile and found it to be a button with its shank intact. The strangest missile of this kind in the Collection is the terminal half of a man's finger, converted into a missile by the impact of a bullet and deeply implanted in a soldier's thigh. This misused finger might taunt the bullet with the much misused phrase, *Sic vos non vobis*.

The damage caused by inert bodies converted into missiles by the impact of high-velocity projectiles, apart from explosive effects, is seen at its maximum in relation to Eyes. The number of soldiers blinded in one or both eyes is greater than in any previous war. This is due, not only to the large size of the fighting forces, but also to the great power of the explosives employed. Colonel W. T. Lister has prepared an exquisite series of eyes destroyed by missiles which is of great value as illustrating the effects of gunshot wounds. These specimens show that a fragment of metal, a little bigger than a grain of sand, if it pierces the coats of the eye, almost invariably entails destructive septic changes.

Colonel Lister's preparations also show that when a missile, moving with a high velocity, enters the eye, it produces the same explosive effects which have been referred to in connection with bullets traversing the head. The Collection contains some specimens showing the tunics of the globe burst by this disruptive force. Lister's Hunterian Lecture contains an admirable description and explanation of these grave injuries.

There is another valuable use for this Collection. Every museum of natural history and allied subjects, to be valuable as well as useful, must grow and expand with the advance of knowledge. As it stands to-day, the Collection contains many carefully prepared specimens illustrating a series of grave and extraordinary injuries. Many of them represent damaged organs and limbs removed in the course of operations from soldiers who survived. Thousands of soldiers remain more or less disabled in consequence of their primary injuries. We want to know the subsequent history of such men. Grave

injuries of the brain have in many instances been followed by recovery: the condition of the men five or ten years later will be of extreme value; the secondary changes following severe cerebral lesions should be studied, and the complete clinical course of the patient duly recorded.

Much valuable knowledge may be gathered concerning the usefulness of many procedures practised for injuries of main arteries. The ultimate effects of ligature practised on the iliac, subclavian, and especially the carotid, arteries, should be followed up and the notes added to the case-histories.

It will be of value to ascertain the fate of bones in which fractures have been 'plated,' and especially those in which gaps have been filled with bone grafts: also the late condition of men's faces who have had extensive plastic operations performed in the neighbourhood of the mouth and nose.

There are many things we require to know in regard to operations performed for the repair of injured nerves. Specimens are needed, not only to demonstrate the changes in the nerve-trunks, but also the secondary changes in the bones belonging to the paralyzed sections of the limbs. Actual specimens are more useful than pages of descriptions.

Zealous officers, interested in surgical pathology, have secured much valuable material for showing the effects of gunshot injuries: if equally enthusiastic in securing specimens illustrating the remote effects of such injuries, and adding them to the Collection, they would enhance its value for future generations of surgeons. It may seem to many that, now the war is closing, it is not necessary to trouble about war wounds in the future. Whatever politicians desire, or statesmen arrange, no thoughtful person can doubt, that as long as the earth is inhabited by human beings, Disease and War will not cease.

JOHN BLAND-SUTTON.

JOSEPH HENRY GREEN.

1791—1863.

THE influence of John Hunter manifested itself in widely different directions in the surgical generations which immediately succeeded him. The physiological side predominated in Abernethy, the purely surgical in Cline, the philosophical in Lawrence. Green alone united the morphological, the surgical, and the metaphysical aspects of Hunter's complex character in such measure that he was able to grasp it in its entirety. Enlightened by a liberal education, Green recognized Hunter's genius; but, early becoming lost in the mazes of transcendental philosophy and the metaphysical speculations which delighted Coleridge, he failed to advance along the paths which Hunter had traced, and remained to the end a philosopher, where he might easily have become a pioneer in surgery.

Born at 11, London Wall, on November 1, 1791, he was the only child of a wealthy London merchant, his mother being sister to Henry Cline, surgeon to St. Thomas's Hospital. A delicate boy, he was educated at Ramsgate and Hammersmith until, at the age of fifteen, accompanied by his mother, he went to Germany, where he spent three years in Berlin and in Hanover.

He was apprenticed to his uncle at St. Thomas's Hospital in 1809, and in 1813—the rule against the marriage of apprentices having been just rescinded—he married Anne Eliza Hammond, daughter of a surgeon at Southgate and the sister of one of Cline's dressers. Mrs. Green survived her husband, but there were no children of the union. For the next two years he lived at 6, Martin's Lane, E.C., where his father was in business, and during this time he acted as Cline's anatomical prosector, giving a regular course of demonstrations on practical anatomy. He obtained his diploma at the College of Surgeons in December, 1815, and immediately began to practise, first at 22, and afterwards at 46, Lincoln's Inn Fields, then the fashionable neighbourhood for surgeons.

In 1816 he was formally appointed Demonstrator of Anatomy at St. Thomas's Hospital, and in this position he was called upon to perform many of the duties which are now assigned to the resident surgical officer in a large general hospital. The summer of 1817 was spent with his wife in a journey to Germany for the express purpose of reading philosophy with Professor Solger, of Berlin. He was elected joint Lecturer on Anatomy and Physiology with Astley Cooper in 1818, and on June 14, 1820, was chosen surgeon to St. Thomas's Hospital in the room of his cousin, Henry Cline the younger, who had died of phthisis at the age of thirty-nine. Shortly after his appointment as surgeon he undertook the Lectureship on Surgery and Pathology in the united schools of St. Thomas's and Guy's Hospitals, again conjointly with Astley Cooper.

In 1824 he gave the first of a series of four courses of lectures on comparative anatomy at the Royal College of Surgeons, in which he dealt for the first time in England with the whole of the animal sub-kingdoms. Richard Owen wrote of these lectures that they "combined the totality with the unity of the higher philosophy of the science. . . . illustrated by such a series of enlarged and coloured diagrams as had never before been seen. The vast array of facts was linked by reference to the underlying unity, as it had been advocated by Oken and Carus." In 1825 he was elected a Fellow of the Royal Society, and in the same year he was appointed Professor of Anatomy at the Royal Academy, a position he held until 1852. In the same year, too, came the unfortunate episode which led to the separation of the United Borough Hospitals. Sir Astley Cooper, on his retirement, wished to assign his share of the lectureship he then held to his nephews, Astley Key and Bransby Cooper. Green—who had paid £1000 for his own half share—agreed, but the hospital authorities declined to sanction the arrangement. Sir Astley thereupon began

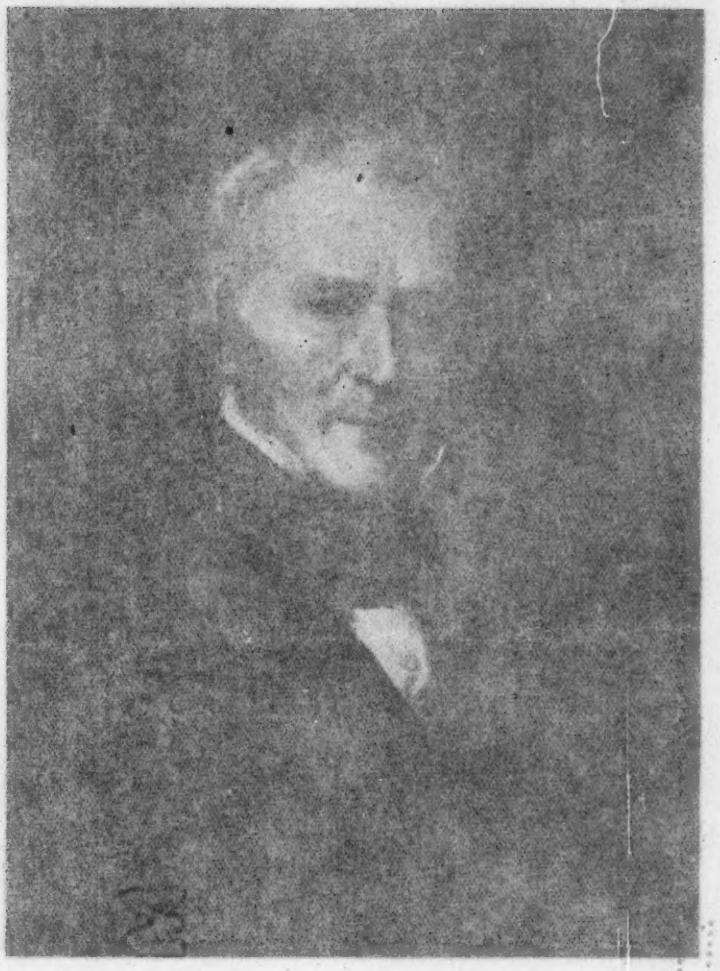
to lecture at Guy's Hospital, and a quarrel ensued. Green, true to his principles, behaved as a gentleman, protested, left the way open for reconciliation, and finally accepted Cooper's apology.

When King's College was founded in 1830, Green was nominated Professor of Surgery —a post he held until 1836, but without resigning his post as Surgeon at St. Thomas's Hospital, which he retained until the year 1853.

He was co-opted to the Council of the College of Surgeons of England in 1835 in succession to William Lynn, surgeon to Westminster Hospital, and in 1846 he became a member of the Court of Examiners in the place of Sir Benjamin Brodie—both appointments being made for life. In 1849–50, and again in 1858–9, he filled the office of President, having previously taken much interest in schemes for the improvement of surgical education and the establishment of the new order of Fellows of the College. In 1860 he succeeded Sir Benjamin Brodie as President of the General Medical Council.

There is no means of knowing when the friendship between Green and S. T. Coleridge first began, though it was probably before 1817, when the poet was living with John Morgan at 70, Berners Street, and it had ripened into intimacy during the Highgate period when Coleridge was living with Mr. Gillman. Even during the most strenuous time of Green's life, from 1824 until 1839, when he was in full practice as a surgeon and teacher, he contrived to spend many hours of every week with Coleridge, learning all that the master could teach. At the death of Coleridge, Green was left as trustee for the children and as literary executor. To the execution of the duties thus imposed upon him Green devoted the main energies of the rest of his life. For thirty years he endeavoured to systematize the Coleridgian doctrines, and for this purpose he improved his knowledge of Greek, learnt to read Hebrew when he was more than 60, and at a still greater age acquired the rudiments of Sanscrit. How great was the task is well shown by Sir John Simon, who says : " Outsiders who knew in general terms that Green had undertaken some literary responsibilities in fulfilment of Coleridge's will, may have supposed him engaged in merely editorial duties with an abundant publishable written text to his hand. Coleridge himself had doubtless contributed to the existence of such a delusion ; for he, with his ardent imagination, had an inveterate mental habit of magnifying the projected into the 'half-done' and the begun into the 'almost ready for publication' . . . But in truth the existence of any such work was mere moonshine. Coleridge had not left any available written materials." Green, therefore, having come into an ample fortune on his father's death, gave up his house in London, keeping only a consulting-room, and settled at Hadley, where by dint of hard work he was able to publish four volumes of *Literary Remains* and *The Confessions of an Enquiring Spirit* as the work of the poet-philosopher, whilst he endeavoured to systematize the teaching in *Religio Laici* and the two volumes of *Spiritual Philosophy* which were published posthumously in 1865 : volumes which contain a statement of first principles and a deduction of the essential doctrines of the Christian Faith upon philosophical grounds.

The influence of Coleridge is seen markedly in Green's two Hunterian Orations—the first delivered in 1840 and entitled *Vital Dynamics*, the second in 1847 which was afterwards published as *Mental Dynamics, or Groundwork of a Professional Education*. In *Vital Dynamics* Green discusses the mental faculties and processes concerned in scientific discovery, and especially insists upon the importance of pure reason as the light by which nature is to be understood. Of John Hunter he says in this oration : " It was his peculiar and eminent merit that he had raised his mind to the apprehension of life as a law, in aid of a science of vital dynamics and as the means of giving scientific unity to the facts of living nature. In what other sense can we understand either his assertion that 'life is a principle independent of organization,' or the purport of the magnificent commentary on his system—the Hunterian Museum. The incalculable advantage of philosophizing in this spirit is plain if we consider that Hunter at once got rid of all hypotheses, fictions, and arbitrary assumptions. By contemplating life as Newton had taught the mechanic philosophers to contemplate gravitation, not as a thing, nor as a spirit, neither as a subtle fluid nor as an intelligent soul, but as a law, he laid the foundation of scientific physiology ;



JOSEPH HENRY GREEN.

From the oil painting in St. Thomas's Hospital.

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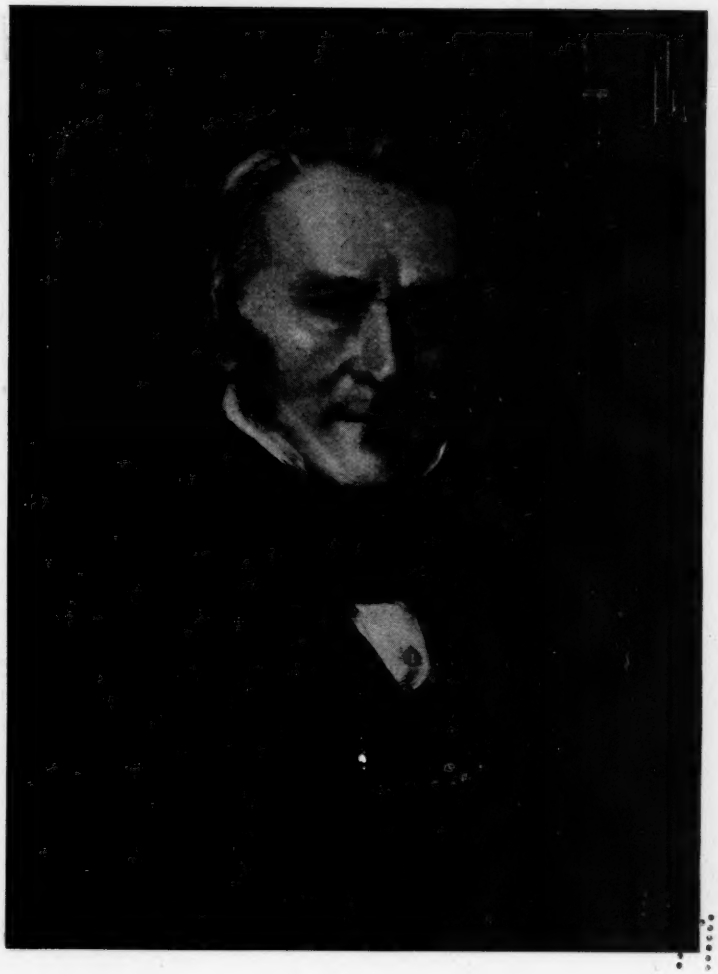


JOSEPH HENRY GREEN.

From the oil painting in St. Thomas's Hospital.

and in that very conception of a law taught us that life is a power anterior in the order of thought to the organization which it animates, sustains, and repairs—a power originative and constructive of the organization in which it continues to manifest itself in all the forms and functions of animated being. This great idea never ceased to work in him as his genius and governing spirit ; and if in his printed works the one directing thought seems occasionally to elude his grasp, yet in the astonishing preparations for his Museum we find him constructing it for scientific apprehension out of the unspoken alphabet of nature, and exhibiting the legislative idea in the mode and measure of its working by bringing together the significant forms and types of life and organic existence."

In like manner in *Mental Dynamics*, Green continues the same line of argument, saying : " It was Hunter's peculiar merit to have first presented the facts of comparative anatomy in, and as, a connected scheme of graduated development, the connection supplied and the aim anticipated in the antecedent unity of the causative law of life . . . and with this science of Comparative or Universal Physiology he has furnished the well-founded and not unconfirmed hope of making every part of the organized creation give intelligibility to every other part, and all to the crown and consummation of all, the Human Frame."

Green died at Hadley on December 13, 1863, and was buried at Highgate. As a surgeon at his best period Green is described as being very skilful, very deliberate, and singularly imperturbable. His lithotomy was thought to be far superior to any performed by the surgeons of his own time, and the results were so successful that the first patient whom he lost at St. Thomas's Hospital after this operation was the fiftieth from whom he had removed a stone.

The portrait is copied, by the kind permission of the Treasurer and Governors, from an oil painting hanging in the Grand Committee Room at St. Thomas's Hospital.

OBSERVATIONS ON A SERIES OF GUNSHOT WOUNDS OF THE HEAD.

By Major GILBERT HORRAX, M.C., U.S.A.

INTRODUCTION.

Although, happily, cessation of hostilities has rendered accounts of gunshot injuries of relatively little value for any immediate purposes, nevertheless, as a complete record of a series of cases treated in a base hospital during the eight months just previous to the Armistice, it has been thought worth while to put together the following statistics and observations.

It was the author's privilege, during the months of August, September, and October, 1917, to be associated with Colonel Harvey Cushing on a surgical 'team' at a casualty clearing station of the B.E.F., where a considerable experience in the operative and post-operative treatment of the cranial injuries of war was obtained. The classification and results in the series of head wounds treated in this forward area were carefully and exhaustively studied by Colonel Cushing in an article published in the British Journal of Surgery, Vol. V, No. 20, 1918. With certain exceptions, the general operative measures and technique employed and described by Colonel Cushing were adopted by the author in the treatment of this series at the base; but reference to a few modifications and special features adaptable to 'base' cases will be made later. In view, therefore, of the foregoing, the present series, though smaller, may serve somewhat as a comparison between a group of cases treated by the same methods, the one relatively soon after injury, the other after a considerably longer period.

Material.—The 222 cases of gunshot wounds of the head which form the subject of this paper include all cases previously unoperated upon which came under the author's care at a base hospital in France during the months March 21 to October 31, 1918. During this period 388 cases which came down after having been operated upon at casualty clearing stations, and 25 cases diagnosed 'concussion,' or 'fractured base,' were also treated or under observation in the author's wards; but no reference will be made to these in the present instance, as they are to be reserved for a future report. The scalp wounds, as might be expected, form a very large percentage of the total number, there being 90 in this category. They will be referred to briefly under *Group I.*

The chief interest in the series lies in the 132 cases of compound fracture of the skull caused by missiles of war. Of the total, 101 were cases of dural penetration, while the other 31 were cranial fracture without injury to the dura. Operation was performed on 93 of the 132. Of the remaining 39, there were 26 recovering so well when they arrived that operative measures seemed unnecessary, and this judgement was substantiated by the fact that all continued to live and do well. The other 13, however, represent cases all of which arrived in an absolutely moribund condition, anywhere from twenty-four hours to four days after injury, usually with large quantities of stinking, infected brain extruding from their wounds, from 50 per cent of which a culture of gas bacillus was demonstrated. No operative measure seemed of any use whatsoever in these cases.

Mortality.—There were no deaths in the group of patients having simple scalp wounds. Among the total number of 132 fracture cases there were 48 deaths, a mortality of 36·3 per cent, and if we take the penetrating cases alone we find 101 cases with 47 deaths, a mortality of 46·5 per cent. These figures do not represent the operative mortality, as they include all cases coming down unoperated to the base, whether or not subjected to operation eventually. Of the 39 unoperated, as noted above, 13 arrived in such shape as to preclude either the possibility or the utility of an operation.

Taking now the operated fracture cases alone, there were 93, of which 35 died, a mortality of 37·6 per cent. Of this number 76 had dural penetrations, with 34 deaths, a mortality of 44·7 per cent. This figure is interesting in that it corresponds closely to the total operative mortality for penetrating cases of Cushing's series, although for his last 45 cases the mortality was reduced to 28·8 per cent.

In commenting upon these statistics it may be said, regarding the operated list, that 14 cases were given the outside chance of benefit from an operation, although the extent of their injury and infection was so great as to make their chances for recovery almost hopeless. Two other cases died from an evident lobar pneumonia, which was demonstrated at autopsy, although novocain had been used as an anæsthetic; one died after a subsequent operation in a home hospital in England; and a fourth from anaphylactic shock within two to three minutes after the intravenous administration of anti-gas-gangrene serum. The remaining cases succumbed to the usual complications of head injury—meningitis, encephalitis, hæmorrhage, abscess, etc.

Inasmuch as Cushing has given us a definite and fairly simple classification of gunshot head injuries, it would seem worth while to take up a further discussion of the series in the groups which he has suggested. Under the subsequent group headings the operated cases only will be discussed, leaving the unoperated to be dealt with separately at the end of the paper.

Group I.—SCALP WOUNDS.

These have been included in the present record simply because it seemed advisable for the sake of completeness. The significance of such wounds at the base is very different from that at advanced medical stations. In forward areas where one receives cases within a few hours after injury, a scalp wound may often form a problem of judgement as to trephining the skull and even opening an intact dura. At the base, however, where infection is already under way after an interval of twenty-four to seventy-two hours, it would seem from our experience to be better policy not to trephine an intact skull, even in the presence of definite neurological symptoms, provided these are not so severe as actually to imperil life. No deaths occurred in the present series from this type of wound.

Group II.—FRACTURES WITHOUT INJURIES TO DURA.

In this group there were 17 operated cases with one death, a 5·8 per cent mortality. Four of the operated cases were trephined, and in one other the enucleation of an eye was necessary in addition to excising the wound. The remaining cases merely had a débridement, as they were doing well upon arrival, which was from one to three days after the reception of the injury. They were watched in the ward from periods of two to four weeks, and in this time none developed abscesses.

Examples of the trephined and untrephined cases follow:—

Case 1.—Pte. A. N. Admitted to field ambulance, April 26, 1918: "Shell wound of head." Casualty clearing station, Sept. 26; no note. Admitted to general hospital, 27th.

History.—Long lacerated gutter wound of right temporo-frontal region, said by patient to be from machine-gun bullet. Was knocked down and unconscious for short period. Later, got up and walked back by himself to the dressing station.

Examination.—Quite conscious and rational at the present time. Slight headache, but no other intracranial symptoms. Neurological examination negative. *X*-ray shows depressed fracture of right temporo-frontal region.

Operation, April 28.—Novocain. Débridement of wound. Dirty scalp, galea, and muscle cut away. Small linear cracks disclosed in skull. Not trephined.

May 20.—No intracranial symptoms. Wound clean and granulating well. Evacuated to England.

Subsequent Report.—Second Western General Hospital, Manchester, Aug. 17, 1918.—Discharged, Class 3, for graduated training.

Case 2.—Pte. S. Admitted field ambulance, Sept. 9, 1918: "Gunshot wound of head." Casualty clearing station, Sept. 9: "Shell wound, left frontal region. Wound probed; fracture present." Gen. hosp., Sept. 10.

History.—Small wound left frontal region ? penetrating. Patient says piece of shell was

picked out. Unconscious for a few minutes after injury. Walked to dressing station with help. No weakness or numbness of right side. No intracranial symptoms now.

Operation.—Novocain. Wound excised. Small depressed fracture disclosed. Burr opening. Area of injury encircled and removed. Extensive shattering of inner table. Fragments of latter picked out. Dura not injured. Closure partial.

Oct. 12.—Wound clean and practically healed. Convalescence uneventful. Evacuated to England.

A third case may be cited, as showing the futility of delay in certain cases with dirty and infected wounds.

Case 3.—Pte. J. Admitted field ambulance, April 12, 1918: "Gunshot wound of head and arm." Casualty clearing station, April 12: "Fractured humerus. Scalp wound." Gen. hosp., April 13.

History.—Knocked down and unconscious. Helmet on at time of injury. Walked to dressing station with assistance. No unilateral symptoms. No hemianopsia. Bad headache.

Examination.—Penetrating wound of right upper arm, with compound fracture of humerus just below joint. Head: large dirty gutter wound over right occipital region; much clot; no hernia made out; cleaned and re-dressed with bichloride. Left pupil larger than right. Fundi: hazy, but no elevation. *X*-ray shows depressed fracture of skull under wound. Deemed best to wait for wound to clean up before operating, as it is very dirty.

April 21.—Both wounds have been doing well, but to-day temperature up to 103·6° and patient complains of headache. Fundi normal. April 22.—Temperature 104°. Headache continues. Much œdema and tenderness of scalp about wound.

Operation.—Ether. Wound partially excised and incisions extended for exposure. Very great œdema and cellulitis of scalp. Moderate-sized depressed fracture disclosed. Area of damage removed by burr opening and encircled with Montenovesi forceps. One large bone fragment in centre thought at first to penetrate the dura over the lateral sinus, but on removing it carefully an unpunctured dura was revealed. Inflammatory granulation tissue thickly overlying the surrounding dura. Wound left pretty widely open and dressed with rubber tissue.

May 1.—Convalescence since operation very good, though œdema of scalp and face persisted several days. Both head and shoulder wounds cleaning up well. Evacuated to England.

The clinical record of the single fatal case is given below, as it is an example of the risk of incising an intact dura through an infected wound. But no matter what the risk, it will be seen from the record that it had to be taken, as it was the one chance which the patient had of recovery. Fatal results do not necessarily follow such a procedure, as the author had three similar cases with recovery in a former base hospital series, which were referred to in Cushing's article. As the risk is, however, much greater at the base hospital than in forward areas in this type of case, we feel that a dura unopened by the initial injury should be incised at operation only under circumstances similar to the following.

Case 4.—Pte. A. W. T. Admitted field ambulance, April 17, 1918: "Gunshot wound of head." Casualty clearing station same day: "Wounded 4.30 p.m. previous day. Head wound clean and re-dressed to-day. No depression detected. Pulse 108. Some vomiting. Mental condition quite clear." Gen. hosp., April 20.

History.—Unconscious for half an hour after injury. Unable to walk. Vomited soon after being hit. Developed weakness of right arm and right leg twenty-four hours after injury. Deep gutter wound across vertex about 3 inches long; foul odour.

Examination.—Marked weakness right arm and leg, though retained some movement. Hypæsthesia over corresponding area. Tongue protrudes to right. Lateral nystagmus. *X*-ray shows depressed fracture at site of wound.

April 21.—Having increasingly severe focal attacks of right side, with loss of consciousness. Very drowsy, and dull mentally.

Operation.—Two p.m. Novocain. Wound excised; tripod extensions. Area of depression removed *en bloc*. The dura not penetrated but extremely tense. It was incised, and copious amounts of clot and disorganized brain were removed by irrigation from a point just to left of longitudinal sinus. Impossible to close dura completely, though tension was greatly reduced. Patient had several convulsions on operating table, but none after the dura had been opened.

April 23.—No attacks during first twenty-four hours after operation, but they have started again to-day and have been very severe. Temperature 102°; patient drowsy but responds rationally.

April 24.—Convulsions continue. Temperature 103°. Wound cultures show streptococcus.

April 26.—Convulsions continued at very frequent intervals. Hernia under wound quite marked. Lumbar puncture; cloudy fluid, which shows Welch-like bacilli by smear. Death at 8.15 p.m., with temperature rising to 106·5°.

Group III.—DEPRESSED FRACTURES WITH DURA PUNCTURED.

In this grouping we come to the transitional cases in which the dura, although punctured by one or more spicules of bone, has not been opened widely, and therefore presents only a slight portal for infection. As might be expected, the prognosis is very favourable; but again somewhat less so at the base than up the line, as the intervening hours of transportation are sometimes sufficient to allow a very serious infection to be set up. This is well illustrated in one of the two fatal cases in this group, as will be seen. In the whole series there were 10 cases with 2 fatalities, a 20 per cent mortality. In one of the two fatal cases a fulminating gas-bacillus infection had rendered the patient semi-conscious before operation, and the other died after a secondary operation in a home hospital in England.

The most striking thing in regard to the treatment of cases in this group is the severe bleeding one is likely to encounter at the operation, although, as has been pointed out, the dural laceration is slight. This, no doubt, is due to the fact that the small spicules of inner table, which in most instances are not entirely detached, often stick into the meningeal artery or the venous sinuses. The removal of these plugs, as the area is taken off *en bloc*, practically always gives rise to unavoidable hæmorrhage. The following is an illustration of such a case, involving the superior longitudinal sinus, with the method of control.

Case 5.—Pte. F. P. Admitted field ambulance, April 17, 1918: "Shell wound in head." Casualty clearing station the same day. No note. Gen. hosp., April 18.

History.—Patient conscious and rational, but somewhat drowsy. Says he was knocked silly; able to walk to advanced dressing station with assistance. Says missile penetrated helmet. Noticed decided weakness and numbness of left leg directly after being hit.

Examination.—No disparity in strength of arms, but left leg weaker than right; no sensory loss; mental condition good. Lacerated tear over cranial vault slightly to the right of mid line. *X*-ray shows extensive depressed fracture, with one very large depressed fragment and many radiating linear extensions.

Operation.—April 19. Ether. Tripod incisions with excision of wound. Bursting fracture disclosed, with cracks running in many directions from a central depressed area. Area around depression, as well as a few large loose fragments, removed by burr openings and Montenovesi forceps. On removing the fragment nearest the mid line it was found that the longitudinal sinus had been badly torn in two places, and a free hæmorrhage occurred before it was wholly checked by means of pieces of muscle obtained from patient's leg. Closed without drainage. April 25.—Wound practically healed per primam. Small amount of bloody serum evacuated from between two stitches. No increase in pre-operative intracranial symptoms. May 1.—Patient bright and responsive. Left leg still a trifle weaker than right; positive Babinski on left; wound clean and healed. Evacuated to England.

Subsequent Report.—Aug. 12. King George Hospital, London.—Wound healed. Motor disturbance slight, and improving; mental state good; no other intracranial symptoms. Discharged unfit for service.

The next case illustrates a type with serious hæmorrhage, in this instance from the meningeal in the subtemporal region. This patient had a large gutter wound which could not be completely closed; but by boring several holes in the exposed skull, as far down as the diploe, granulations sprang through very quickly and the area covered over far sooner than if they had been left merely to come across from the edges.

Case 6.—Pte. D. Admitted field ambulance, April 24, 1918: "Compound fracture skull." Casualty clearing station same day: "Fracture skull; brain exposed. Severe hæmorrhage." Gen. hosp., April 25.

History.—Patient conscious and fairly rational, but very drowsy. Says missile was machine-gun bullet, and that he was knocked down and unconscious, but got up and walked to dressing station with assistance. Remembers no other details. Large gutter wound of right temporo-frontal region filled with blood-clot.

Neurological Examination.—Left face and arm weak and hypæsthetic; left leg also slightly weak. Knee-jerk much increased on left; positive Babinski on left. No clonus. Pupils equal; eye movements normal. *X*-ray shows depressed fracture under site of wound, with two foreign bodies in scalp.

Operation.—Ether. Clot cleaned out and wound edges excised; tripod extensions. Skull shows depressed area with radiating cracks from which fresh blood is coming freely. Burr opening, and spherical decompression made with rongeurs. Dura penetrated by one depressed fragment and meningeal artery torn by edge of same, so that it was bleeding vigorously; hæmorrhage finally

controlled by means of piece of muscle between skull and dura proximal to bleeding point. Dura under fairly normal tension; not incised. Only partial closure possible because of size of wound.

May 5.—Patient had moderate headache for two to three days after operation; intermittent temperature, averaging about 101°, but at one time going to 104°. Temperature now between 98° and 99°. Several perforations made with burr in uncovered bony area exposed. May 17.—General condition excellent. Granulations have completely covered exposed bone, having come up through burr holes previously made. Neurological examination negative. Evacuated to England.

Subsequent Report.—July 19. Wound almost healed; no paralysis; cerebration good; reflexes normal. Headaches, and periodic dizziness.

Notified for return to Australia as permanently unfit.

There were two cases of cerebellar injury in this group. The record of the case which follows is given rather in detail, as it contains many interesting features. The conservative treatment by lumbar puncture was tried at first for several days with this patient, but his headache became increasingly severe and his temperature remained constantly a little elevated. After operation he had several convulsions over a period of forty-eight hours, but after that made a rapid recovery.

Case 7.—Pte. R. L. Admitted field ambulance, April 26, 1918: "Shell wound of head." Casualty clearing station same day, no note. Gen. hosp., April 27.

History.—Unconscious after injury until arriving at dressing station. Marked headache. Has not been able to stand. Sight unaffected. Could hear well in both ears. The wound was of a small, penetrating type, in the suboccipital region just to left of mid line.

Examination.—Temperature 100°; pulse 80; mentality rather passive, but answers questions readily. Eyes have a slight tendency to deviation to right; occasional slight nystagmus to right and left. Speech unaffected. Arms: tone very slightly depressed in both. No ataxia. Reflexes: Knee-jerks equal; biceps, right feeble, left absent. *X*-ray shows depressed fracture of sub-occiput, extending into foramen magnum.

FIG. 1.—*Case* 7. Showing attitude of left shoulder and arm in walking.

April 28.—On account of patient's headache lumbar puncture was performed, and 25 c.c. of bloody fluid not under great tension was withdrawn. April 29.—No relief from headache, which continues very severe.

Operation.—May 1. Novocain. Left half of 'crossbow cerebellar flap' with excision of wound. Extensive depressed fracture exposed as shown in *x*-ray. Burr opening was made, and depressed area removed with rongeurs. One large loose fragment which extended down to the foramen magnum was extracted with some difficulty but without bleeding. Dura slightly punctured at one point low down over the left cerebellar hemisphere. Considerable dural tension, and therefore a small incision was made and about 50 c.c. of fairly clear fluid evacuated. At this point patient said that his headache was quite relieved. Wound closed in layers with silk without drainage.

May 2.—Patient had a convulsion with some respiratory difficulty last night; but recovered, and seems in good condition to-day, except that he has a return of his headache. Lumbar puncture was done and 20 c.c. of blood-stained fluid withdrawn, with slight relief from headache. Two more mild convulsions this afternoon.

May 3.—Several more convulsions during last twenty-four hours, but headache is decidedly better. Fundi show moderate œdema but no elevation. May 5.—No convulsions during past two days, and headache becoming constantly better. Patient quite responsive and rational. Wound clean; healing well. May 17.—Convalescence rapid and uneventful since last note. Sutures removed on sixth day after operation; wound clean and quite solid; patient sitting up in bed. No headache, vomiting, dizziness, or nystagmus.

May 19.—Patient up and about to-day. Has questionable tendency to fall to the left. Holds left arm somewhat flexed at side (*Fig.* 1). Left shoulder elevated. Evacuated to England.

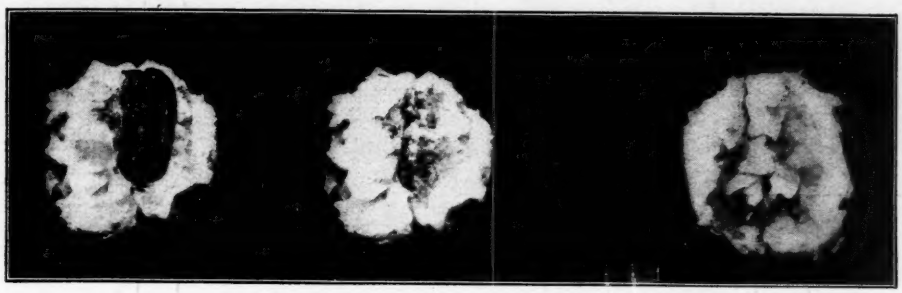
Subsequent Reports.—London, May 20.—Arrived in good condition. No abnormal neurological symptoms. Oct. 10.—No headache, motor or sensory disturbance; mental state clear. Invalided, permanently unfit.

The next case illustrates a type with foreign body lodged in the skull, but falls into *Group III* because the dura was only moderately punctured.

Case 8.—Pte. T. A. W. Admitted field ambulance, April 18, 1918. "Shell wound in the head." No casualty clearing station number or notes. Gen. hosp., April 19.

Examination.—Somewhat drowsy and sweating. Answers questions rationally. No weakness or sensory loss. No hemianopsia. Wound of penetrating type, right post-parietal region. *X* ray shows depressed fracture under site of wound with foreign body sticking through skull.

Operation.—April 21. Ether. Tripod incisions with excision of wound. Depressed area removed *en bloc* (*Fig.* 2, *A*, *B*, *C*). Dura punctured in two places; not opened further. Closed tight without drainage.



A. *B.* *C.*

FIG. 2.—*Case* 8. (*A*) Depressed area with foreign body *in situ*. (*B*) Foreign body lifted off. (*C*) Under surface of the depressed bone, showing spicules of inner table which pierced dura. (⅔ natural size).

April 25.—Patient had temperature up to 103·4° for two days following operation, due to collection of serous fluid under wound, which was evacuated through opening between two stitches. Culture shows streptococcus. Temperature now normal, and patient doing well. May 12.—General condition excellent. Wound clean and healed. No neurological symptoms except slight headache. Evacuated to England.

Subsequent Report.—London, Sept. 3.—Wound healed. No motor, sensory, or visual disturbance; mental state clear. Invalided unfit.

The Fatal Cases.—These were two in number, and the case records are given in full. The first is another instance of sinus injury necessitating the use of muscle to control hæmorrhage. Although the patient had a very extensive wound, and depressed fracture which smelled gassy, he made an excellent recovery and was discharged to England three weeks after operation. At this time he still had a small granulating area in the middle of his wound (*Fig.* 3). A subsequent report showed that he died after a secondary operation.

Case 9.—Pte. P. C. Admitted field ambulance, Aug. 23, 1918: "Compound depressed fracture of skull." Casualty clearing station same day: "Pulse full, slow, and regular; answers questions; rather restless." Gen. hosp., Aug. 24.

History.—Remembers nothing about injury or other past events. Wound covered an extensive, dirty, lacerated area over mid-line of vertex in frontal region. Considerable dirt and hair sticking between loose, up-ended bone fragments.

Examination.—Patient entirely disoriented. Shows well-marked frontal syndrome. Very irritable, restless, and at times tries to get up out of bed and walk about; talks irrationally; is incontinent.

Operation.—Aug. 25. Ether was used on account of the patient's total loss of self-control. Wound edges thoroughly excised, necessitating cutting away of a large amount of scalp. A very extensive comminuted and depressed fracture was disclosed, lying directly over the longitudinal sinus. Many linear fracture lines radiating from the depressed area in all directions. A single burr opening was made, and from this the depressed area was encircled with Montenovesi forceps, no further openings being necessary on account of extensive breaking up of the area allowing a piecemeal removal. Dura found to be pierced by fragments of inner table at several points. Two of these points were directly over longitudinal sinus, and the hæmorrhage upon removal required muscle for control. Dura over the right hemisphere so far as exposed seem fairly normal and without undue tension. On the left side, however, the dura was discoloured and showed an inflammatory exudate on its surface in patchy areas, and the tension in this hemisphere seemed

considerably increased. There was a distinct difference in tension on palpation first to the left and then to the right side of the longitudinal sinus. Dura not opened. Only partial closure possible owing to large amount of scalp which had been excised.

Aug. 30.—Patient has been somewhat more rational and less restless since operation, but his power of self-control is still almost gone, and he complains at the smallest trifles. Fundi are normal. Has considerable headache, which seems to come on in spasms. Sept. 3.—Headache better. Fundi remain normal. Sept. 15.—Unstable mental condition has nearly cleared up now, and headache has subsided. Practically no evidence of his former frontal syndrome. Wound is clean and healed except for one slightly granulating place in centre (*Fig.* 3). Evacuated to England.

Subsequent Report.—Oct. 20.—The patient developed septic meningitis after a further operation, and died on above date. Autopsy showed abscess in left frontal region, and meningitis.

FIG. 3.—*Case* 9. Wound at time of discharge to England.

The other case was a second example of a cerebellar wound in this group. Its interest lies in the fact that such a rapid and destructive gas infection should develop so quickly from the slight portal of entry in the dura.

Case 10.—Pte. R. J. B. Admitted field ambulance, Aug. 8, 1918: "Shell wound in head. Dressed." Casualty clearing station: "Dressed." Gen. hosp., Aug. 9, 10 a.m.

History.—Was wounded the morning of Aug. 8, and on that day was given 500 units antitoxic serum without gas serum. Patient very ill on admission; very pale, pulse rapid and thready; semi-conscious, and cannot be made to give any coherent reply to questions. No definite cerebellar signs are demonstrable, although he has a penetrating wound over the subocciput. Laboratory report says: "Smear—scattered *B. Welchii*, moderately numerous. A few cocci. Culture—*B. Welchii*." *X*-ray shows depressed fracture of suboccipital region, with foreign bodies sticking through the skull.

Operation.—2 p.m. Novocain. Crossbow cerebellar incisions, with excision of wound. Large depressed fracture of suboccipital region just to right of mid-line. Foreign body removed from amid the fragments of the external table. Area around fragments removed as usual; dura over right cerebellar hemisphere was extremely tight, and had been penetrated by the bone in two places. Owing to the extreme tension the dura was opened widely, and there was an immediate extrusion of nearly the whole right cerebellar hemisphere. The fungus thus produced had an extremely foul odour of gas bacillus, and was of the usual soft disorganized consistency of a typical Welch infection. Much of this soft tissue was washed away by irrigation, but practically no reduction in size of fungus could be obtained. Partial closure, leaving area about fungus wide open. Patient showed no obvious effects one way or another from his operation, and went downhill rapidly, dying at 6.15 p.m.

Autopsy showed an almost entirely disorganized right cerebellar hemisphere, a basilar meningitis, and dilated lateral ventricles.

Group IV.—FRACTURES WITH BONE FRAGMENTS SHOWERED INTO THE BRAIN. CORTICAL TISSUE USUALLY EXTRUDING. WOUND OFTEN OF GUTTER TYPE.

We come now to that type of wound which produces not only cranial and dural damage, but serious trauma to the brain itself. Following Cushing's classification, the cases in which the cerebral injury does not involve the lateral ventricle will be discussed under the above heading. It will be seen, too, that this group does not include cases in which a metallic foreign body has been retained in the brain. Most often the missile cuts a deep gutter through scalp and skull, the bone at the point of contact being driven at right angles inward, sending a shower of fragments through the dura and into the cerebral tissue. The portal for infection therefore is large, and by the time such patients reach the base they usually have an evidently infected hernia cerebri, with brain tissue smeared about the wound and in the hair, which is often uncut. Frequently these patients are drowsy and cannot be made to respond well, or if they do, no very reliable history can be gathered.

In the series there were 20 examples of *Group IV*; of these, 7 died, a mortality of 35 per cent. The site of the wound was parietal or vault in 8, frontal in 4, temporal in 4, occipital in 2, and cerebellar in 2.

Looking at this group as a whole, two very striking facts are brought out. To show this, a word must be said in regard to the operative technique. During the first four months, March 21 to July 31, a primary closure of the operative wound was nearly always practised, with subsequent reopening after twenty-four to forty-eight hours if there was marked bulging of the hernia under the skin, accompanied by a rise in temperature. During the second period, August to November, only one primary closure was attempted, all the other wounds being left wide open at operation, allowing the hernia, if there were one, to be directly exposed through the skin edges. All seven deaths occurred in the first period, which comprised twelve cases; while the eight cases operated upon from August to November all recovered.

The other feature of this group is that in five out of the seven fatalities a culture of the *B. Welchii* was grown from smears of the infected brain tissue procured at operation. In a sixth case a smear showed the presence of typical Welch organisms, but no culture was taken. This patient died suddenly, while in good condition, the evening after operation, from what looked like anaphylactic shock immediately following a minute intravenous injection of anti-gas-gangrene serum.

Considerable interest attaches to many individual cases in the group. The following is an example of one of the earlier operations, with primary closure of the wound, which had to be reopened later. This patient had perhaps the most stormy post-operative period of any, and eventually made a most remarkable recovery. Too great emphasis cannot be laid on the fact that this and other similar cases could not possibly have been pulled through without the intelligent and devoted work of the ward nurses. It has been the writer's good fortune to have had a most capable head nurse, who was especially trained in neurological work, to superintend the ward care of all the cases reported here. She, in turn, trained the other nurses under her in the ward in the detailed management of patients with serious head injuries. This 'team' work not only saved the time and effort of the medical officer, but also the lives of many of the unfortunate men thus wounded.

Case 11.—L.-Cpl. W. W. Admitted field ambulance, April 18, 1918: "Bullet wound in head." Casualty clearing station, same day, with note: "Evacuate lying." Gen. hosp., April 19.

Examination.—Patient practically unconscious; cannot respond rationally. Left hemiplegia. Deep reflexes exaggerated on left. Pupils equal; fundi negative. Wound: penetrating type, right parietal, near vault; brain extruding. *X*-ray shows extensive depressed fracture with indriven fragments. No foreign body intracranially.

Operation.—Ether; tripod incisions; very extensive depressed and bursting fracture disclosed just to right of longitudinal sinus. Area removed piecemeal, and many large detached, depressed, and indriven fragments picked out. Severe bleeding from cerebral vessels checked largely with hot saline. Closure with rubber-tissue drain. Patient in rather poor condition at end of operation, and given usual measures for treatment of shock.

April 21.—Patient has shown no tendency to become any more conscious since operation. Breathing is very bad to-day. Cyanotic and dyspnœic, with Cheyne-Stokes respiration at times. There is an excessive amount of mucopurulent secretion, which is coughed up from time to time and constantly drains out of patient's mouth. Foot of bed elevated to assist in this drainage. Patient seems practically moribund. April 22.—Condition very slightly improved to-day. Dressing done; wound bulging, and therefore several stitches removed and wound opened up. Fairly large hernia disclosed; considerable old blood and clots expressed from around fungus. Culture of this showed streptococcus. April 24.—Patient again in a little better condition. Fungus increasing in size, and wound, therefore, opened up farther. April 28.—Culture from fungus again shows streptococcus. May 2.—Fungus very large in size, but patient is definitely better and more responsive. Taking nourishment well. May 7.—Fungus still larger—about the size of a very large duck's egg, but beginning to clean up now. General condition improving every day. Left hemiplegia continues complete. May 17.—Fungus no larger, and decidedly cleaner. Beginning to granulate. May 30.—Hernia entirely receded, leaving clean granulating surface. Patient now feeding himself with right hand; left still practically useless. Possibly a slight movement in left arm.

June 14.—General condition excellent, though left side shows only very slight tendency to improve as yet. Evacuated to England.

The next case is quoted as a direct comparison with the above. It is a typical example of *Group IV*, with extensive cranial and cerebral damage, the infecting organism being the streptococcus as in the preceding patient. In this instance, however, is seen the happy outcome of leaving the wound wide open at operation, followed by an almost uneventful convalescence and a rapid recovery from marked intracranial symptoms.

Case 12.—Pte. G. H. Admitted field ambulance, Sept. 24, 1918: "Gunshot wound of head; penetrating." Casualty clearing station, same date: "Compound fracture; brain exposed." Gen. hosp., Sept. 26.

Examination.—Gutter wound, 1½ in., over left parieto-occipital region. Brain extruding. Patient entirely aphasic; right hemiplegia; right homonymous hemianopsia. *X*-ray report at casualty clearing station shows no foreign body, therefore no further *x*-ray taken.

Operation.—Novocain. Tripod incisions, with excision of wound. Area of depressed fracture removed with rongeurs. Dura found widely open over an area of 1in. by 1¾in. in two diameters. Many large and small bone fragments removed from brain to a depth of 2 in. Track washed out with saline solution and sucked as clean as possible with a catheter. Hernia entirely reduced at end of operation. Partial closure, leaving opening over dural penetration. Culture taken.

FIG. 4.—*Case* 12. Wound at time of discharge to England.

Sept. 28.—First dressing. Wound seems clean except for slight serous discharge. Small hernia, which is level with scalp. Patient had one focal attack to-day involving right side, not severe. Beginning to say a few words. Oct. 2.—No further focal attack. Beginning to talk a little, and can move right arm and leg slightly. Wound perfectly clean. No further protrusion of hernia (*Fig.* 4). Cultures from wound show an anaerobic diphtheroid bacillus and streptococcus. Oct. 17.—Convalescence uneventful; is talking more every day, showing only slight traces of aphasia at present. Right arm and leg still somewhat weak, but gaining in strength steadily. Wound clean. Patient sitting up in bed; can read, and is able to feed himself. Evacuated to England.

The only case in the earlier days of the series to be treated by the open method, i.e., leaving the wound wide open after operation, is shown in the record herewith. Indeed, in this patient, the large area of scalp destruction, as well as the fact that the hernia could not be very greatly reduced at the time of operation, rendered complete closure impossible. The fungus was dressed very carefully with gutta-percha tissue, keeping pressure from it by a ring of cotton-wool, and despite the presence of gas bacilli as shown by means of smear and culture, a perfectly smooth convalescence ensued.

Case 13.—Lance-Cpl. F. C. P. Admitted field ambulance, May 8, 1918: "Shell wound in head; compound depressed fracture frontal bone." Casualty clearing station, same date: 'Evacuate lying.' Gen. hosp., May 9.

History.—Patient conscious and fairly rational, but drowsy and not responsive. Says he was knocked down and unconscious after being hit. Only walked a few steps afterwards. Vomited on train. Has had severe headache ever since.

Examination.—Neurological evidence negative other than preceding. Wound: large lacerated area over right frontal region; very dirty. Quite apparent extensive depression and comminution of bone. Culture taken, with immediate report of *B. Welchii* from smear. *X*-ray shows the depressed fracture noted, and also a shrapnel ball in patient's upper lip.

Operation.—Ether. Very thorough cleaning and irrigating of wound area with bichloride preliminary to operation. Many torn pieces of scalp and hair driven in between the various bone fragments. Wound excised and incisions extended laterally for exposure. Fragments removed piecemeal, as fracture being so large it did not seem wise to enlarge the cranial defect by going outside the damaged area with Montenovesi forceps. In addition to the depressed fragments there was a long linear fracture running back across the right parietal region to the occiput, as shown in the *x*-ray plate. Dura widely torn, and opened over an oval area 2½ × 2 cm. Large amount of disorganized brain and clots extruded spontaneously as soon as depressed fragments were removed; several indriven fragments palpated with catheter and removed with forceps. Track cleaned by suction, but even after a painstaking débridement there remained a fairly large hernia which could not be reduced. Complete closure was impossible, and the centre of the wound was left open around hernia. Shrapnel ball removed from lip.

May 11.—Temperature normal; patient in much the same condition as before operation. Dressing shows hernia not increasing and appearing quite clean. Cultures from wound show *B. Welchii* and *Staphylococcus aureus*. May 15.—Temperature remains normal. Hernia remains clean and is about the size of a hen's egg. Patient now bright and alert. No intracranial symptoms of any sort. May 20.—Hernia beginning to granulate.

June 1.—Patient sitting up in bed. Hernia granulating well. June 15.—Convalescence uneventful. Hernia fully granulated and starting to recede. July 1.—Hernia has entirely receded leaving clean granulating area level with scalp. Neurological examination negative. Evacuated to England.

Subsequent Reports.—London, Oct. 14, 1918.—Wound quite healed. Skin over trephined area firm and healthy. No motor, sensory, or visual disturbance. No aphasia. Mental state good. Sent home unfit for service.

A letter from patient, Oct. 31, says he is enjoying himself at home, and that he was given a skull cap when discharged from hospital in England.

Unfortunately, photographic facilities were not at hand at the time the above case was being treated in the wards; therefore a very similar type of injury will be quoted next, with illustrations of the fungus, and again of the wound before discharge to England.

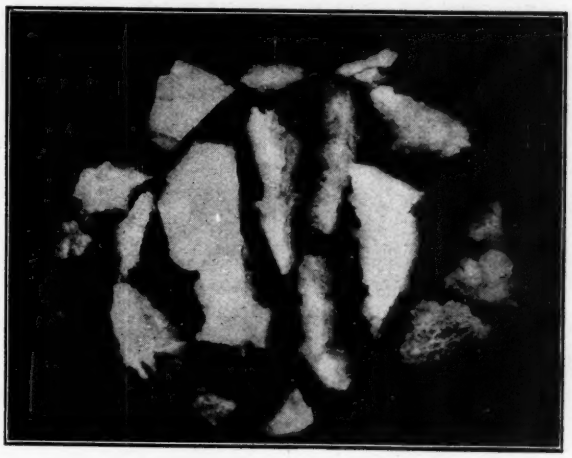


FIG. 5.—*Case* 14. Indriven fragments of inner table removed from brain at operation. (⅔ natural size.)

Case 14.—Pte. A. J. Admitted field ambulance, Oct. 15, 1918. No note. Casualty clearing station, same date: "Gutter wound left parietal. Dura open." Gen. hosp., Oct. 16.

On Admission.—Patient conscious, but has complete motor aphasia and right hemiplegia. No history obtainable. The wound is a 4-in. gutter over left parietal region, with large amount of foul, gas-smelling brain extruding.

Operation.—Oct. 17. Novocain. Wound excised and incisions extended at either end. Area of depressed fracture encircled by burr-holes and Montenovesi forceps. Dura found widely torn over an area of 1¼ by 1½ in. in two diameters. Much pulped brain and clots washed out by irrigation with salt solution. Large number of inner table fragments were removed from within the brain to a depth of 2 in. (*Fig.* 5). Catheter suction was then applied and more disorganized tissue evacuated. The previously existing hernia was entirely reduced at the end of operation. Partial closure, leaving opening over area of dural penetration.

FIG. 6.—*Case* 14. Hernia five weeks after operation.

Oct. 19.—Cultures from wound show *B. Welchii*, streptococcus, and *Staphylococcus aureus*. First dressing. There is a slight hernia nearly level with scalp edge; seems quite clean. Patient's general condition good. Oct. 21.—Cultures again show *B. Welchii* and a diplococcus. Oct. 25.—Hernia protruding somewhat beyond scalp now, but seems clean.

Nov. 1.—Patient picking up words rapidly, but no change in the paralysis of right side. Hernia about the size of small hen's egg, and granulating nicely. Nov. 15.—Hernia rather larger than at last note, but patient's general condition continues good, and he is bright and responsive in every way, although still unable to say any

very great variety of words. Nov. 22.—Speech a little better each day. Right foot moved slightly for first time to-day. Hernia slightly reduced in size (*Fig.* 6). One very small bone fragment discovered just under surface of granulations, and picked out. Dec. 15.—During last three weeks hernia has entirely receded, and the granulating area is now nearly covered over by epithelium (*Fig.* 7). General condition excellent. Moving right leg slightly more, and right arm also is beginning to have slight movement. Speech has improved very much, although he still cannot carry on a perfect conversation. Evacuated to England.

Subsequent Report.—Yorkshire, Jan. 1, 1919.—(By letter from patient): "I am writing to let you know I am going on all right. My speech is coming better, and sometimes I can raise my right hand above my head."

FIG. 7.—*Case* 14. Practically healed wound at time of discharge to England.

Several writers on head injuries of war have noted the very extraordinary recovery of function even when serious damage has been done to important cerebral centres. Whether the initial loss of motor or sensory faculties, etc., is due to concomitant œdema, or whether because of pressure from hæmorrhage and the indriven fragments of bone, has not yet been determined. Probably both factors come into play. The record which follows illustrates well how great this recovery may be, even when a severe infection has complicated the original brain injury.

Case 15.—Sapper E. M. **Fracture with indriven fragments of bone injuring left hemisphere extensively. Complete aphasia and right hemiplegia. Streptococcal meningitis. Operation. Recovery.**

Admitted field ambulance, April 13, 1918: "Gunshot wound of head." Casualty clearing station, April 14, and the note: "Entry left parietal eminence. Hemiplegia. Evacuate." Gen. hosp., April 15.

On Admission.—Patient completely aphasic, with right hemiplegia, and deep reflexes exaggerated. No Babinski or clonus. Left side normal. Questionable right hemianopsia; fundi normal. Wound of small, penetrating type, left postparietal region. *X*-ray shows depressed fracture at site of wound, with indriven bone. No intracranial foreign body.

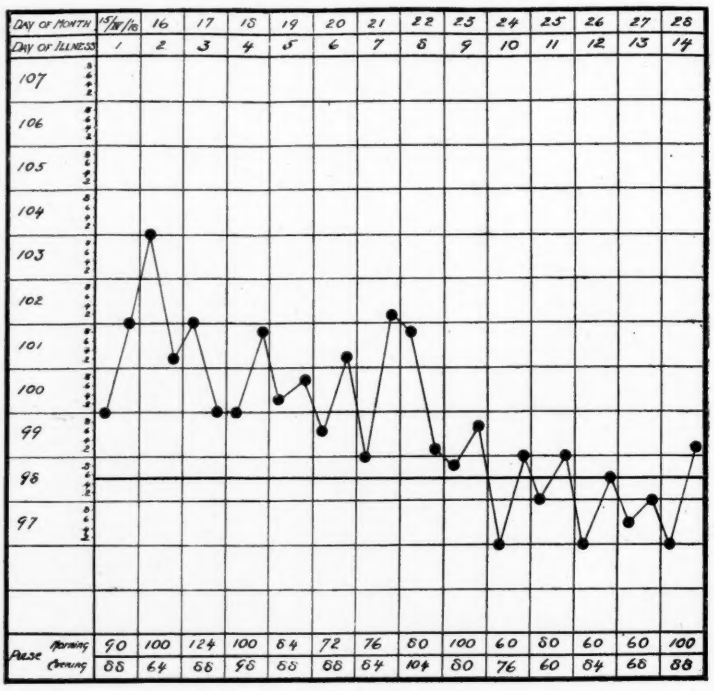


FIG. 8.—*Case* 15. Temperature chart.

Operation.—Novocain. Tripod incisions. Area of bone around depressed fracture removed fairly well *en bloc*. Dura rather extensively torn; indriven fragments palpated along track with catheter, and removed with forceps. Disorganized brain and

clots removed from track by suction. Several troublesome meningeal bleeding points which it required application of muscle to control. Closure without drainage.

April 16.—Temperature up to 104° (*Fig.* 8), but wound looks in good condition, without bulging. Not opened. April 17.—Temperature 102° and wound bulging slightly. Re-opened, and considerable clot and necrotic tissue evacuated. Culture report from wound shows streptococcus and *Staphylococcus aureus*. April 18.—Temperature subsiding. Patient having focal attacks of right face, more broken-down blood-clot and disorganized tissue were evacuated from wound. April 21.—Patient somewhat drowsy during last twenty-four hours. Temperature up to 103° to-day. There is a fairly large hernia now, bulging through the flaps where wound was reopened. Culture from wound again shows long-chained streptococcus. April 24.—Temperature subsiding, and patient evidently improving. Beginning to use a few words. May 1.—Hernia not increasing in size and seems to be doing well. There is a considerable discharge of yellowish-green pus coming from around it. May 5.—Hernia beginning to granulate. May 8.—Hernia subsided, leaving granulating area level with skull. May 12.—Patient using more words every day; can carry on fairly good conversation; understands spoken language perfectly. Motor: right leg and foot can be moved weakly; right arm can be slightly extended and flexed. There is a very slight motion of fingers and wrist on right hand. May 26.—Right arm and leg can now be moved about very well, and the strength of this side is evidently improving every day. Patient's aphasia has almost entirely cleared up; he understands perfectly, reads to himself and aloud quite well. No evidence of any hemianopsia. Wound clean and nearly healed. Evacuated to England.

Subsequent Reports.—By letter from patient's sister, July 2, 1918: "My brother is going on very well. His speech has returned to practically its normal capacity. He is knocking about, but at present has no feeling down his right side." Sept. 19.—Sandon Hill Hospital, Stafford. Right leg improving considerably. Right arm still weak, but useful. Aphasia practically gone.

Since one sees so many cases of simple fracture of the base which do well under the conservative treatment of lumbar puncture, it is worth while giving details of a case which at first was taken to be of this type and treated accordingly; but later, operative measures proved the fallacy of the supposition. This patient, like many others, came down the line two days after injury in a very drowsy and entirely irrational condition. He was too unmanageable to get an *x*-ray plate of any great value, but when he became increasingly drowsy after repeated lumbar punctures, it was evident that an operation was the only alternative. The surprising results of this procedure are given below.

Case 16.—Gnr. M. B. **Fractured base, with bone fragments driven through dura. No relief from repeated lumbar punctures. Operation, with further opening of dura. Rapid recovery.**

Admitted field ambulance, Aug. 8, 1918: "Shell wound, head." Casualty clearing station, same date. No note. Gen. hosp., Aug. 10.

On Admission.—Patient entirely irrational and quite unruly. Gets up out of bed and wanders about; has no idea what he is doing. Right side of face and head greatly swollen and ecchymotic. Right eyelid completely closed with œdema. One questionably penetrating wound over the right subtemporal region. *X*-ray unsatisfactory.

Aug. 11.—Same general condition. Lumbar puncture under ether showed 20 c.c. of old bloody fluid under more than normal pressure. Aug. 13.—Still restless, but more drowsy. Lumbar puncture showed 15 c.c. of clear xantho-chromatic fluid. Aug. 14.—Patient semi-conscious; fundi showed hazy nasal margins, with nasal side of discs probably elevated about one diameter. Optic cups and laminæ obscured.

Operation.—Novocain. Vertical incision over temporal and subtemporal regions, as for decompression, with careful avoidance of small septic wound at lower end. Temporal muscle thick and œdematous. Depressed fracture of lower portion of temporal bone disclosed, with linear extensions forward and posteriorly. Burr opening above fracture, and wide decompression made. Three large loose bone fragments were removed from lowest portion of the fracture, two of which had been driven through the dura, tearing it extensively. There was considerable venous oozing from the base after the removal of these fragments, where temporal lobe had been pushed away from the skull. Dura further incised, extending the incision from the torn area at the base, up over the temporal lobe. Large masses of subdural and subcortical clots were extruded and washed out, as well as much disorganized cerebral tissue. Tension somewhat reduced, but not sufficient to close dura, which was left widely open. Very careful closure of muscle and galea with fine silk in layers. Rubber-tissue drain left at upper end, extending beneath the dura.

Aug. 16.—Patient much more responsive since operation. Will now obey simple requests. Taking nourishment well. Wound seems quite clean. No undue tension over decompressed area. Drain removed. Aug. 20.—Unruly at times, and at times fairly drowsy. Fundi still show hazy nasal margins. As the œdema has subsided from the right side of the face, there has now become evident a complete oculomotor nerve palsy on the right—i.e., he is unable to elevate right eyelid,

and movements of right eyeball are restricted to outward rotation and slight upward movement. Sept. 9.—Convalescence uneventful since last note. His irrational condition has cleared up very rapidly, and for the past ten days he has been up and about ward. Wound clean and perfectly healed except for a small granulating mass at lower end (*Fig.* 10). Fundi normal. Oculomotor palsy still practically complete (*Fig.* 9), though he can now elevate right eyelid slightly. Evacuated to England.

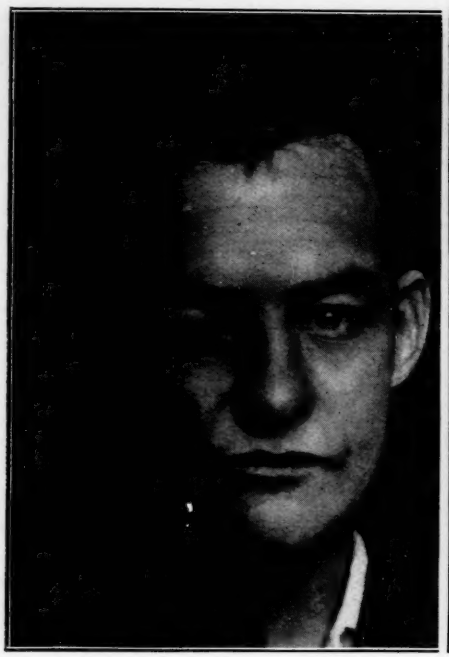


FIG. 9.—*Case* 16. Showing oculomotor palsy, with inability to raise right eyelid.

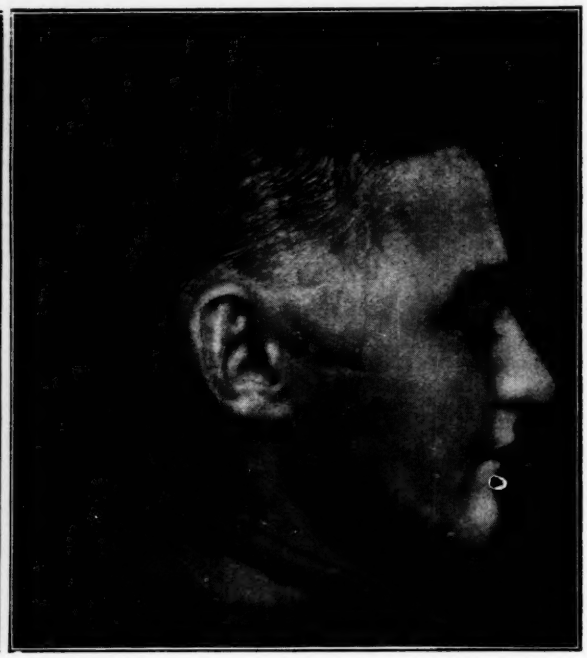


FIG. 10.—*Case* 16. Wound at time of discharge to England.

The Fatal Cases.—A short record of each of the seven fatal cases of this group is appended, together with the autopsy findings. In all probability two of these patients might have recovered if their wounds had been left open at the time of operation. A third was doing quite well three days after operation, when he died, presumably from sudden medullary compression. A fourth case was the one mentioned earlier in this paper as having succumbed to anaphylactic shock.

Case 17.—Pte. A. C. Admitted gen. hosp., April 18, 1918, two and a half days after reception of his wound. Patient drowsy and apparently irrational.

On Admission.—There was a large, lacerated gutter wound over right occipital region, with large amount of extruding brain. Neurological examination showed left homonymous hemianopsia; left leg weak and anæsthetic. Bilateral ankle-clonus, more marked on left. Questionable Babinski on both sides.

Operation, April 19.—Tripod incisions. Extensive depressed fracture, with large number of indriven fragments. Area of fracture removed as usual. Track cleaned by suction with catheter, and all fragments that could be palpated were removed. Closure without drainage.

April 24.—Patient did fairly well for first forty-eight hours after operation; but despite the reopening of the wound on the second day, he became worse, with rising temperature and marked hernial protrusion, and died at an early hour this morning. Several culture reports showed a profuse growth of *B. Welchii*.

Autopsy revealed purulent meningitis and encephalitis. At the site of the wound several small pieces of bone were found which had not been removed at operation.

Case 18.—Pte. H. C. Admitted gen. hosp., April 17, 1918, thirty-six hours after reception of wound. Semi-conscious and irrational; can give no history. Has slight aphasia. Small penetrating wound left temporal region, with brain extruding. *X*-ray shows fracture at site of wound, with foreign body just sticking through skull.

Operation.—Novocain. Tripod incisions; foreign body extracted. Area of depressed fracture removed with rongeurs; many indriven bone fragments removed through dural opening. Track cleaned by suction with catheter. Closure with rubber-tissue drainage.

April 28.—Patient showed improvement for forty-eight hours, and then temperature became elevated; his aphasia and drowsiness increased, and marked hernia developed at site of wound. Death at 2.45 p.m. to-day. Cultures from wound showed *B. Welchii* and streptococcus.

Autopsy.—Purulent basal meningitis, with infection of ventricular fluid. No bone fragments found at site of wound.

Case 19.—Rfm. J. E. Admitted gen. hosp., April 11, 1918, fifty-six hours after reception of wound. Patient very dizzy, and having considerable headache, but no vomiting. Drowsy; moderate dysarthria. Marked fine nystagmus to right and left. Says he was very unsteady on feet when walking to dressing station.

Wounds: (1) Of penetrating type, post-mastoid region, with questionable cerebrospinal fluid leak; (2) Through-and-through wound of left hand, with fracture of carpus. *X*-ray shows large foreign body deep in neck at level of first cervical vertebra. No fracture of skull made out.

Operation.—Novocain. Wound excised and incisions extended for exposure. Depressed fracture of left suboccipital region disclosed, with cortical tissue extruding. Incomplete operation done. Several small bone fragments picked out from beneath hole in dura; foreign body recovered from neck. It had evidently hit the skull a glancing blow, causing the damage as stated above. Closure with drainage. Cultures from wound showed presence of *B. Welchii* and streptococcus.

April 14.—Patient had been doing quite well, but had a sudden respiratory failure this morning, and died within a few minutes, at about 4.30 a.m. Probably medullary compression.

Autopsy shows destruction of two-thirds of the left lobe of the cerebellum. Slight meningeal injection but no meningitis. Remainder of brain normal.

Case 20.—Pte. G. C. F. Admitted gen. hosp., April 11, 1918, thirty-six hours after reception of wound. Patient drowsy and partially irrational. No neurological signs. Reflexes normal. Gutter wound over occipital region, with brain extruding. *X*-ray shows depressed fracture at site of wound, with indriven bone fragments. No metallic foreign body intracranially.

Operation.—Novocain. Very foul-smelling gassy wound; odour typical of *B. Welchii*. Tripod incisions; area of bone around fracture removed as usual. Many indriven bone fragments palpated and removed with catheter. Disorganized brain and clots sucked out; dichloramine-T; partial closure.

April 15.—Temperature rose to 103° day after operation, and lumbar puncture gave 30 c.c. cloudy fluid under great pressure. Temperature continued to rise; patient became irrational, and died at 2 a.m. to-day.

Autopsy.—Thin hæmorrhagic exudate over right hemisphere. Nearly the whole of the posterior half of left hemisphere showed destruction by encephalitis.

Case 21.—Pte. A. P. Admitted gen. hosp., April 11, 1918. Complete right hemiplegia, with knee-jerks exaggerated and positive Babinski on right. Deep reflexes also lively on left. Small penetrating wound, just to left of mid-line of vertex. Odour is that of *B. Welchii*. Cerebral substance extruding. *X*-ray showed depressed fracture, with indriven bone fragments. No metallic foreign bodies intracranially.

Operation.—Novocain. Four incisions radiating from wound. Area of depressed fracture removed. Many large and small indriven bone fragments removed from brain up to depth of 4 cm. One bone fragment had penetrated longitudinal sinus and caused some troublesome bleeding. Tracks sucked out with catheter. Partial closure.

This patient lived eleven days after operation. He had an initial rise of temperature to 104°, which subsided on the fourth day and remained nearly normal until the seventh day, when it again began to rise and continued to do so until the day of his death, reaching 106·2°. Numerous cultures from wound showed presence of *B. Welchii*. A hernia developed at the site of the wound which increased in size until the patient's death.

Autopsy showed meningitis, with purulent exudate over both hemispheres. Brain showed considerable destruction in both frontal lobes anterior to, and around, the site of the wound, with encephalitis.

Case 22.—Lance-Sgt. F. R. Admitted gen. hosp.. April 18, 1918, about thirty-six hours after reception of wound. Patient conscious but quite irrational. Has definite frontal syndrome. No paralysis or other neurological signs. Deep horizontal gutter wound across forehead, with cerebral tissue extruding over an area 4 by 2½ cm. Wound has a distinct foul odour of gas infection.

Operation.—Novocain. Wound excised; area of extensive depressed fracture removed; many indriven bone fragments picked out from within the brain, as well as pieces of dirt and clothing. Track cleaned by suction with catheter. Complete closure impossible.

April 19.—Patient was doing very well after operation, with a temperature only slightly elevated, but mental condition remained irrational and irritable. Inasmuch as smears of the wound showed presence of gas bacillus it was decided to give an injection of anti-gas-gangrene

serum. Upon the introduction of probably less than 1 c.c. of the serum into the patient's vein he complained that he was choking and unable to get his breath ; no further serum, therefore, was introduced, but the patient immediately went into a condition which was taken to be anaphylactic shock, with extreme cyanosis and dyspnœa, at the same time becoming practically pulseless. Within less than a minute he was entirely unconscious, and died in about fifteen minutes.

Autopsy.—Brain showed subdural clot extending over the entire right hemisphere. The tissue destruction from the wound on the left side led posteriorly near the mid-line, ending just anterior to the tip of the ventricle. A large amount of the anterior parts of both frontal lobes was destroyed. No evidence of meningitis.

Case 23.—Gnr. P. S. Admitted gen. hosp., April 26, 1918, thirty-six hours after reception of wound. Complains of severe pain in back of head and down the neck. Speech slow, drawling, and indistinct—i.e., a fairly typical cerebellar dysarthria. Slow nystagmus to right, more rapid to left. Also a fine nystagmus on looking upward. Hearing : considerable loss, both ear and bone, on right side. Ataxia very marked with right hand ; none on left. Right leg shows slight uncertainty, left leg normal. Linear wound, 1 in. long, midway on a line between the inion and the tip of the right mastoid ; smaller, apparently penetrating wound behind tip of left mastoid. *X*-ray showed a large piece of shell-casing just outside the subocciput on the left side, and a fracture on the floor of the cerebellar fossa close to the foramen magnum.

Operation.—April 27. Novocain. The foreign body was found quite superficially in the left side of wound. Removed, and a drain left in place. Flap was turned down from the right sub-occipital region. Small depressed fracture disclosed, which was removed by burr opening and rongeurs. Dura widely penetrated, and large amount of softened brain and clot extruded spontaneously after the bone had been taken away. Many indriven bone fragments also palpated and removed, and track cleaned by suction with catheter. Wound closed, leaving rubber-tissue drain.

May 1.—Cultures from wound have repeatedly shown presence of streptococcus. Patient did fairly well for forty-eight hours following operation, but began to fail on the third day, with rising temperature. Wound was re-opened and moderate-sized hernia developed. He died at 8 p.m. to-day, with stiff neck and positive Kernig, evidently a terminal meningitis.

Autopsy.—Showed almost complete destruction of right cerebellar hemisphere, with several small indriven fragments of bone which were not obtained at operation. The right cerebral hemisphere and the base of the brain showed a thick purulent meningitis.

Group V.—PENETRATING WOUNDS WITH PROJECTILE AS WELL AS BONE FRAGMENTS LODGED IN BRAIN.

We have here a more serious type of cerebral injury than in the group just preceding, and the mortality is consequently somewhat greater. It will be remembered that we are still dealing with cases in which the ventricles have not been penetrated. There were 15 examples of *Group V* in the series, with 6 deaths, a mortality of 40 per cent. The wound of the skull, in this type, is usually a relatively small, punched-out hole, but whereas in *Group IV* the bone fragments are as a rule showered only into one hemisphere, in these cases the heavier metal, with greater penetrating capacity, is nearly always driven far inwards, and in at least one-half of the instances in this series was lodged in the opposite side of the brain from the wound of entrance. It is evident therefore that the cerebral damage is potentially greater than in *Group IV*, because extending more deeply, and indeed it is sometimes true that a very small piece of shell may cause infinitely more destruction to the brain than a much larger one, according to the centres through which it passes and the number of blood-vessels it happens to encounter *en route*. On the whole, however, there is no question but that the larger the missile retained, the more apt is the case to prove fatal, a fact which was well borne out in this series.

As Cushing has pointed out, the greater danger in cases where a missile has been retained comes from the fact that the piece of metal has already traversed infected material outside the body—hair, clothing, helmet, etc.,—and organisms are consequently carried far into the brain, where they give rise to latent trouble. In *Group IV*, although the area of brain exposed to the outside may be much larger, nevertheless the infection is more superficial, and consequently better taken care of both by the cerebral tissue and by careful dressing methods, to which we shall refer later.

Site of Wound.—The parietal region was the area entered by missiles in 7 of the 15 cases of this group. The point of entrance in the other instances was occipital in 3, suboccipital in 1, frontal in 2, and temporal in 2. This differs quite decidedly from the

sites of penetration in Cushing's series, as he found that the temporal and suboccipital regions were most frequently entered by missiles in patients surviving until operated upon at a casualty clearing station. The immediate explanation which offers itself in a 'base' series is that the temporal and suboccipital wounds of this type have been caused by comparatively small missiles; otherwise the patients would have been killed, and the survivors, coming down perhaps two to six days subsequent to injury, are doing well, and are therefore not subjected to operation after so long an interval. This surmise is substantiated by the fact that 6 out of 7 cases in *Group V* which were not operated upon had temporal wounds.

The question of the relation of the helmet to head injuries cannot be discussed in this article, because at least half the patients with penetrating wounds were either semi-conscious or irrational to such a degree that no great reliance could be placed on subjective data, the neurological findings being almost entirely objective.

As in the preceding group, the very grave results of a gas-bacillus infection in cases not operated upon early is quite evident. Of the 6 fatalities, 5 showed cultures of the Welch organism, and 2 of these survived for three weeks after operation, while being treated with gas-bacillus antitoxin. In 2 of the 9 surviving cases a growth of *B. Welchii* was obtained.

The foreign body was removed in 7 out of the total 15 cases—in 4 of the patients who recovered, and in 3 of those who died. In the cases in which they were not removed, the missiles had either crossed to the opposite hemisphere from the side of entrance or, in the case of frontal and occipital wounds, had almost completely traversed the hemisphere in which they lay. In these patients a careful and thorough cleaning of the track by suction with a catheter, and removal of the bone fragments driven in at the site of penetration, was deemed the wisest form of procedure.

A good illustration of this relatively conservative treatment is seen in the following case report.

Case 24.—Pte. H. K.—**Foreign body lodged in left occipital lobe, from entrance in left frontal region. Aphasia and right-sided weakness. Débridement of track of missile. Recovery, with marked remission of speech and motor symptoms.**

Admitted field ambulance, June 28, 1918; "Gunshot wound of head." Casualty clearing station same date, with the following note; "Small penetrating wound, left frontal region; unconscious; suspect fracture of calvaria. Evacuation lying." Gen. hosp., June 29.

On Admission.—Nearly unconscious. Does not respond coherently, but makes slight attempts to carry out requests. Small penetrating wound left frontal region. Right side stiff and somewhat weaker than left; grip definitely so. Some loss of sensation over whole right side; practically complete motor aphasia. Reflexes: Knee-jerk and biceps response exaggerated on right; normal left. Positive Babinski on right. No clonus. *X*-ray showed depressed fracture at site of wound, with foreign body in left occipital lobe.

Operation.—Novocain. Wound excised. Four radiating incisions for exposure. Area around small punctured hole in skull removed *en bloc*. Round hole in dura corresponding in size to foreign body, i.e. about 1 cm. in diameter. Several ounces thick blood-clot evacuated through this hole by exerting slight pressure around it. Several small pieces of indriven bone fragments also removed. Catheter introduced to depth of about three inches, and considerable amount of disorganized brain tissue sucked out. No attempt made to find foreign body, as *x*-ray had shown it lying too far posteriorly. Partial closure of wound, leaving opening directly over point corresponding with dural perforation.

July 3.—Patient has improved steadily since time of operation. Temperature normal. Right-sided weakness continues, as does also his aphasia, though he is beginning to say a few monosyllables. Wound clean, and now shows a small fungus, which, however, does not come above the scalp level. Cultures from wound have shown *Staphylococcus albus*. July 13.—Patient improving steadily. Quite responsive and shows no drowsiness. Beginning to say several more words, and has no difficulty in understanding even the most complicated sentences. Reads to himself, and says he can understand perfectly well what he reads; but is unable to read aloud. Weakness of right side clearing rapidly, there being now very little difference in the legs, though there is still slight difference in arms. Right face is also still definitely weaker than the left. July 30.—Hernia now has granulating surface, and is still just level with scalp. Right side can be moved practically as well as left, and there is no demonstrable difference in the strength of the two legs and arms. Right facial weakness still present. Very faint loss of sensation on the

right side. Aphasia clearing up; using more words every day. Can read and write perfectly. Aug. 7.—Further improvement since last note. Evacuated to England.

Subsequent Report.—London, Aug. 9. Arrived in good condition; was discharged to Brondesbury Park Military Hospital.

An example of the type with shell fragment crossing to the other hemisphere is seen in the next case. Here again is to be noted the fact that the patient also had an incomplete though very definite motor aphasia, in spite of the missile being comparatively small and the site of entrance posterior-parietal. Such an aphasia is seen very frequently in gunshot wounds of the head, even when the penetration is far posterior in the left hemisphere, and the track, as in the present instance, is apparently at a considerable distance from Broca's area.

Case 25.—Pte. I. Admitted field ambulance, April 24, 1918: "Shell wound head." Casualty clearing station same date, with note: "Penetrating wound. Patient has vomited." Gen. hosp., April 26.

On Admission.—Conscious but exceedingly drowsy. Accurate history unobtainable, because of his partial motor aphasia. Small penetrating wound, left post-parietal. *X*-ray shows depressed fracture at site of wound, with indriven bone and rather small metallic foreign body in opposite hemisphere. Right pupil slightly larger than left. Right arm and face weak and hypæsthetic. Legs normal. Astereognosis of right hand. No hemianopsia. Incomplete motor aphasia.

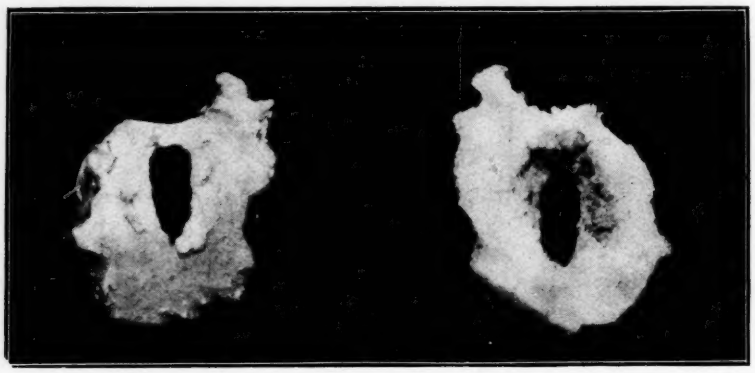


FIG. 11.—*Case* 25. Outer and inner surfaces of area removed *en bloc* at operation. (⅔ natural size.)

Operation.—Novocain. Tripod incisions. Small punched-out hole in skull exposed, corresponding in size to foreign body seen in *x* ray. Area removed *en bloc* (*Fig.* 11). Small hernia through dural opening. Catheter introduced as usual and track sucked out, reducing hernia entirely. Several indriven bone fragments also palpated and removed; dichloramine-T; no attempt made to remove foreign body because of its inaccessibility in opposite hemisphere. Wound closed with silk, without drainage.

April 28.—Patient quite comfortable and without headache. Temperature normal. Wound clean and without tension. May 1.—Slight convulsion this morning, but is feeling well this afternoon, with normal temperature. May 11.—No further convulsions. Aphasia has entirely cleared up. Strength of arms equal. No demonstrable astereognosis. Very slight hypæsthesia on right side. Evacuated to England.

Subsequent Report: London, Oct. 15.—No motor, sensory, or visual disturbance. No aphasia. Mental state clear. Invalided unfit for further service.

The record of one of the survivors of a gas-bacillus infection in this group is cited next, and this, too, although operation was not performed until seventy-two hours after injury.

Case 26.—Sgt. G. T.—Admitted field ambulance, July 28, 1917: "Bomb wound head." Casualty clearing station, with note: "Small wound left forehead. Right pupil larger than left." Gen. hosp., July 29.

History.—Patient very dizzy after injury; got up within a few minutes and walked back to dressing station with assistance. Noticed nothing wrong with legs or arms.

On Admission.—Neurological examination entirely negative, with exception of the fact that patient is having headache. Small penetrating wound in right forehead, with brain extruding. *X*-ray showed depressed fracture at site of wound, with two small foreign bodies intracranially.

Operation.—July 31. Novocain. Tripod incisions with excision of wound. Area round small punctured hole in skull removed *en bloc*; small perforation of dura disclosed. Catheter introduced through dural opening and disorganized brain removed by suction. Many pieces of indriven bone also removed. Partial closure, leaving small opening over dural perforation.

Aug. 3.—Two different cultures from wound have shown the presence of *B. Welchii*. August 14.—Convalescence absolutely uneventful. No hernia has developed at site of wound, which has stayed perfectly clean. No intracranial symptoms. Neurological examination negative. Evacuated to England.

The following case shows quite plainly that considerable intracranial damage can be caused by a very minute fragment of metal. The developments at operation bore out the marked symptoms of cerebral pressure which were noted in the preliminary clinical examination.

Case 27.—Cpl. W. M. Admitted field ambulance, Sept. 2, 1918: "Shell wound head and left hand." Casualty clearing station same date, with note: "Small penetrating wound left temporal region." Gen. hosp., Sept. 4.

On Admission.—Patient in irrational semi-conscious condition. Very irritable, and complains continually. Is having very bad headache. Slight sensory aphasia. No paralysis made out. Very small penetrating wound, temporo-parietal region, left side. *X*-ray shows depressed fracture at site of wound, with very small intracranial foreign body.

Operation.—Novocain. Tripod incisions, with excision of wound. Skull showed a very minute crack about $\frac{1}{8}$ in. long, with no further damage discernible. Had the patient not showed clinical evidence of severe intracranial disturbance it is doubtful whether anything more would have been done. However, upon introducing the point of a knife into the small crack a little semi-fluid material which resembled disorganized brain escaped. A burr opening was therefore made to one side of the crack and a small circular decompression done. This disclosed a perforation of the dura about $\frac{1}{4}$ in. long and $\frac{1}{8}$ in. wide. Through this opening much more disorganized material and clots were evacuated both by getting patient to cough and by suction through a catheter. At a depth of 2 in. within the brain at the end of the track a resistance was felt by palpation with a small catheter. A small iron nail was therefore introduced, the end of a magnet brought up to this nail, and the foreign body was easily extracted. Partial closure, leaving opening as usual over site of dural perforation.

Sept. 6.—Patient doing well. More rational, though still very drowsy. Still complains of headache. Sept. 17.—Wound clean and healed. No discharge or hernia. Headache gone. Patient now perfectly conscious, rational, and of normal mentality. Evacuated to England.

The most interesting of all the surviving cases was that given in the next report. It was one of the very few instances in which a secondary operation was necessitated because hæmorrhage at the primary procedure prevented a complete débridement. The part involved—that directly over the lateral sinus—is perhaps the most difficult of any cranial area in which to work. The other astonishing feature in this patient was his very high temperature forty-eight hours after the first operation, associated with complete temporary blindness. At this point it was thought that he would surely succumb to a rapid basilar meningitis; but during the next two days he rallied extraordinarily, and after the foreign body and remaining pieces of bone were removed, made a fairly rapid convalescence.

Case 28.—Pte. H. A. T. Admitted field ambulance, Sept. 2, 1918: "Bullet wound of head." Casualty clearing station same date: "Penetrating wound behind right ear." Gen. hosp., Sept. 4.

On Admission.—Patient conscious and rational, but drowsy and having considerable headache. Right facial palsy of peripheral type. No left-sided weakness of face, arm, or leg. Lateral nystagmus to right and left. Partial sensory loss of right face. Lacerated penetrating wound just behind right ear above mastoid; brain extruding. *X*-ray showed depressed fracture of right superior mastoid region, with indriven bone fragments and fairly large metallic foreign body, intracranial (*Fig.* 12).

Operation.—Novocain. Wound excised and right half of cerebellar cross-bow flap made. Area of cranial perforation encircled with Montenovesi forceps. Several pieces of indriven bone palpated through the dural penetration which was disclosed after the removal of the depressed cranial area. Two or three pieces of these were picked out with forceps, but finally one of them was found to be sticking through the lateral sinus. Upon removing this piece a very profuse hæmorrhage occurred, which was stopped only with some difficulty by the placement of muscle. At this stage it was deemed unwise to proceed further. Partial closure.

Sept. 6.—The patient has become more drowsy since operation; temperature 105° this evening (*Fig.* 13). Says that his vision is gone completely, and that he is now unable to distinguish

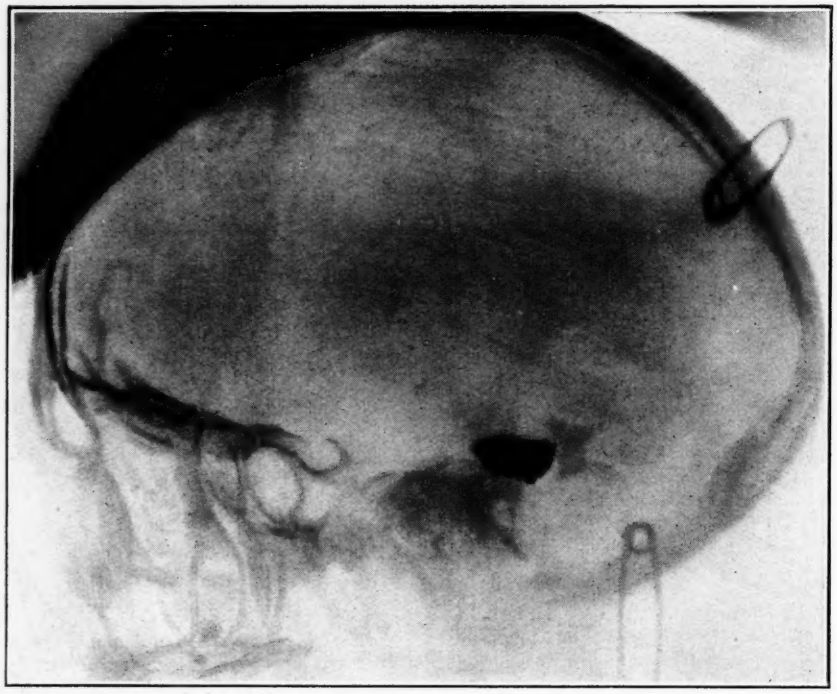


FIG. 12.—*Case* 28. *X*-ray showing foreign body and two of the indriven bone fragments.

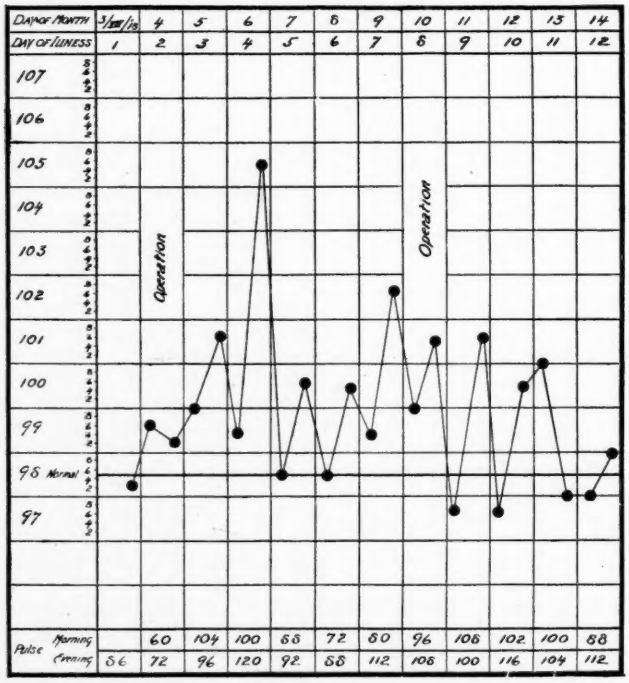


FIG. 13.—*Case* 28. Temperature chart.

even between light and dark. Dressing shows small hernial protrusion at site of wound, with considerable brownish discharge. Previous culture has shown streptococcus and Welch-like bacilli. Sept. 8.—Patient's temperature has come down to 100° during the last forty-eight hours. Is much more responsive, and vision has once more returned.

Second Operation.—Novocain. Wound partially opened up and surface of dura and brain carefully cleaned with pledgets of cotton. Track was again found after a careful search. Three pieces of indriven bone discovered wedged together in track between the tentorium cerebelli and the under surface of the right occipital lobe. Below these, and further inward at a depth of 1½ in. the metallic foreign body could be felt, and finally seen by gentle retraction of the occipital lobe.

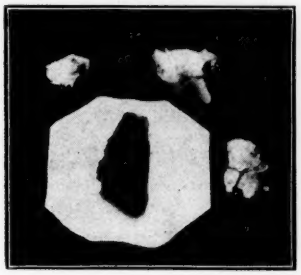


FIG. 14.—*Case* 28. Foreign body and bone fragments (⅔ natural size) removed at second operation.

FIG. 15.—*Case* 15. Wound at time of discharge to England.

The bone fragments were removed with forceps with some difficulty and without starting any bleeding from the damaged place in the sinus, over which the muscle had now taken a firm hold. After removal of the piece of bone the foreign body was also easily withdrawn (*Fig.* 14).

Oct. 4.—Patient has made an uneventful convalescence since second operation. Vision is normal and his right nystagmus has disappeared. There still remains slight right facial palsy. Mentality normal. Wound practically healed (*Fig.* 15). Evacuated to England.

The Fatal Cases.—The clinical records of the two following cases are given in detail, because of points having considerable interest. Both are illustrations of severe gas infections which showed some apparent improvement because of treatment with Bull's serum, and lived much longer than one would have expected, judging from other examples not treated in this way. The first of these cases also shows, unfortunately, the result of not being able to wait for an *x*-ray during a rush period. When the foreign body was finally removed at a secondary operation, it was found to have just eroded into the ventricle, making a terminal ventriculitis inevitable.

Case 29.—Pte. W. T. W. Admitted field ambulance, April 17, 1918: "Shell wound head." Casualty clearing station, same date: no note. Gen. hosp. April 18.

On Admission.—Patient nearly unconscious; can give no history. Responds very slightly. Longitudinal sinus syndrome very well marked. Left leg rigid; right somewhat stiff. Deep reflexes exaggerated in both legs; positive Babinski both sides; no clonus. Round penetrating hole over vertex just to left of mid line; brain extruding. *X*-ray not taken owing to rush of cases.

Operation.—Novocain. Tripod incisions, with excision of wound. Area around penetration of skull removed without special difficulty. Many bone fragments indriven just to right of longitudinal sinus. One piece had pierced the sinus lightly, but the bleeding was checked without any special features. Track of missile cleared by suction with catheter. Closure without drainage.

April 20.—Cultures from wound show *B. Welchii* and *S. albus*. Temperature up to 103° yesterday, but down to 101° to-day. Patient very restless and responds very slightly. Wound re-opened and large amounts of very foul-smelling necrotic tissue evacuated. Large hernia present. April 24.—Temperature subsiding on the whole, and patient a little more responsive. Hernia dressed by placing around it pledgets of cotton which had been soaked in anti-gas-gangrene serum. Patient also given 20 c.c. anti-gas-gangrene serum intramuscularly. April 30.—

Temperature elevated and irregular during past five days, but patient's general condition seems better on the whole. Anti-gas-gangrene serum continued, both locally to hernia and intramuscularly (*Fig.* 16).

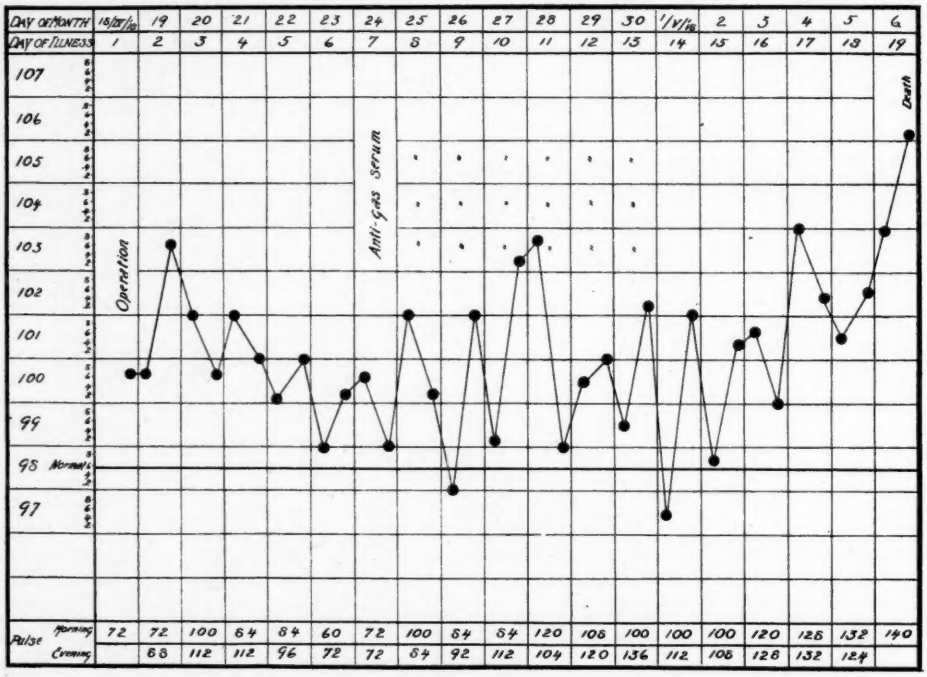


FIG. 16.—*Case* 29. Temperature chart, indicating times of treatment with anti-gas-gangrene serum.

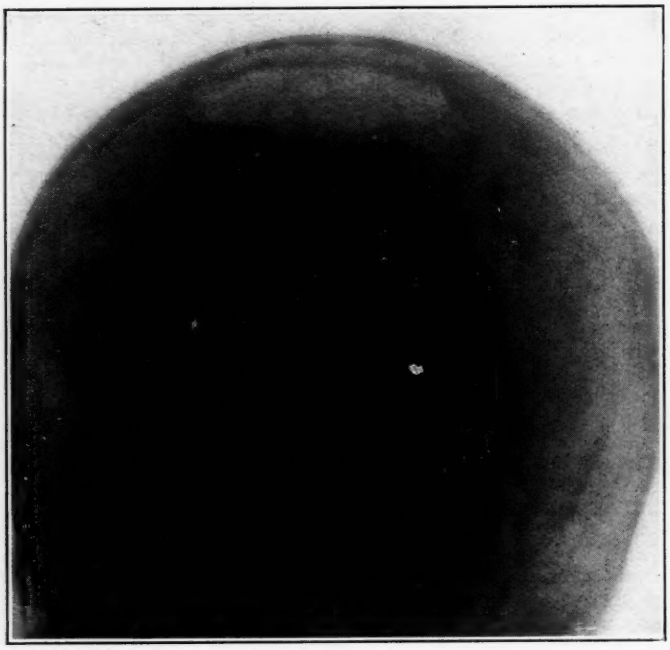


FIG. 17.—*Case* 29. *X* ray taken after original operation, showing position of foreign body and area of bone removed previously.

Daily cultures since last note have shown the presence of *B. Welchii*, but the organisms seem to be less profuse than at first and their growth much more feeble.

May 5.—Although patient's condition has been very poor his head was *x*-rayed yesterday, and a large foreign body disclosed lying at a depth of about 2 in. within the brain directly under the wound of the vertex (*Fig.* 17); therefore, as a last resort, patient was taken to the operating room and the foreign body removed without special difficulty through the track, which was still present. May 6.—Patient went down-hill very rapidly during next twenty-four hours, and died to-day with temperature of 106·4° (*Fig* 16).

Autopsy. — Moderate destruction around the track through which the missile was removed. Track communicates on the right side with the lateral ventricle, the foreign body having apparently just eroded into it. This ventricle

contains a moderate amount of thin purulent fluid, but the fluid in the left ventricle is practically clear. There is a cloudy exudate over the base.

Case 30.—Rfm. E. H. Admitted field ambulance, April 17, 1918: "Gunshot wound of head." Casualty clearing station, same date; no note. Gen. hosp., April 18.

On Admission.—Patient in fairly rational state, but quite drowsy; no accurate history obtainable. Right pupil larger than left. Left arm slightly weaker than right; left hemianopsia. Penetrating wound, right occipital region. *X*-ray shows depressed fracture at site of wound, with foreign body resting very slightly intracranially.

Operation.—April 19. Ether. Tripod incisions. Area of depressed fracture removed *en bloc*; foreign body easily extracted just below dura. There is a strong odour of gas bacillus. Many indriven bone fragments removed, and track cleaned by suction with catheter. Hernia not entirely reduced. Closure without drain.

April 21.—Culture from wound shows *B. Welchii* and *S. aureus*. Patient doing badly; temperature up to 101°. Wound re-opened. Hernia has increased very greatly in size, and has extremely gassy smell.

April 26.—Repeated cultures have shown *B. Welchii*. Patient has therefore been treated with local applications of anti-gas-gangrene serum to the hernia, as well as by intramuscular injections. Hernia very large now.

May 2.—Temperature has subsided nearly to normal, but patient gradually sinking and has been only slightly responsive the last few days. Died this evening without terminal rise of temperature.

Autopsy showed a very extensive encephalitis of the right occipital lobe, with almost complete destruction of this lobe. Bilateral ventriculitis. Meningitis.

The next case also came down during a 'push.' By the time his turn for operation came his wound was doing fairly well, and was therefore simply dressed for several days. It was seen, however, that his cerebral injury was too great to be taken care of simply by conservative means, as an abscess had developed around the foreign body. This abscess was drained, and the foreign body removed at operation two weeks after the initial injury. His intracranial condition improved decidedly after this procedure, but he died of lobar pneumonia at the end of another two weeks.

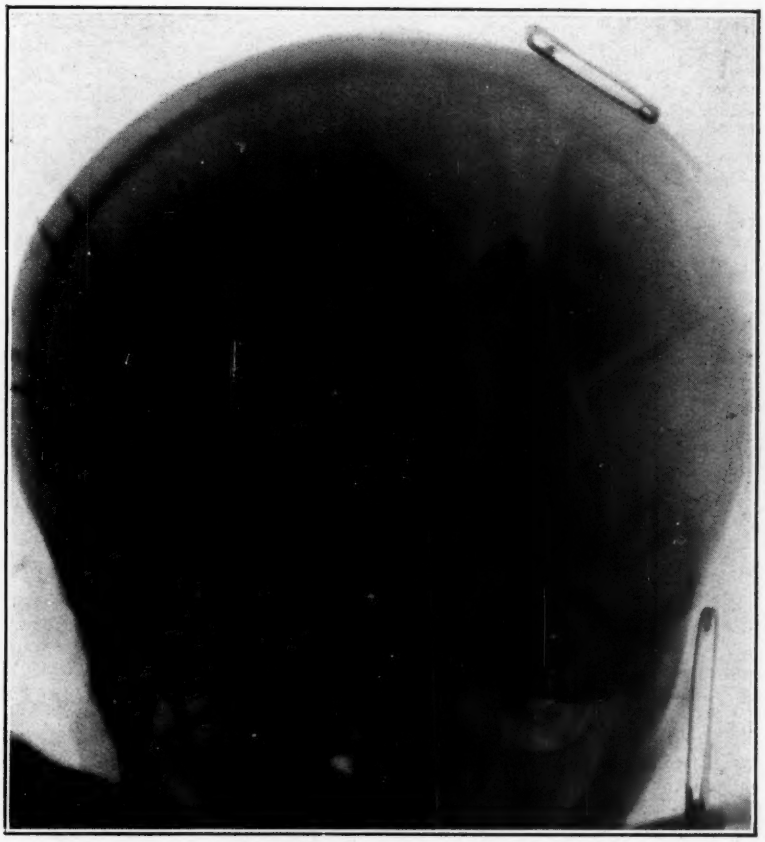


FIG. 18.—*Case* 31. *X*-ray showing position of foreign body and extent of fracture.

Case 31.—Private P. N. L. Admitted field ambulance, Sept. 1, 1918: "Gunshot wound of head." Casualty clearing station, same date: "Wound right parietal region; hernia cerebri; left paralysis. Patient conscious and can talk. Pulse good." Gen. hosp., Sept. 4.

On Admission.—Patient semi-conscious and entirely irrational, talking in delirium. Left hemiplegia. Lacerated area over right parietal region, with masses of dirty stinking fungus extruding. Re-dressed.

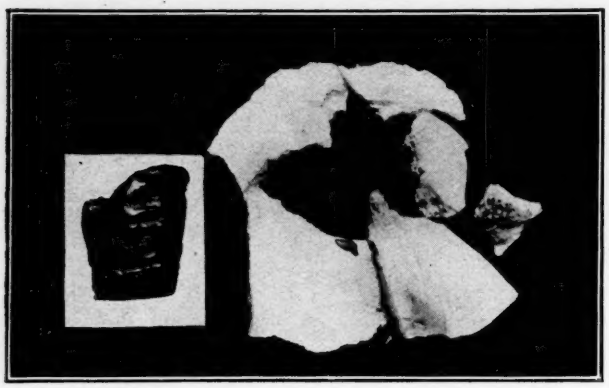


FIG. 19.—*Case* 31. Foreign body and bone fragments removed at operation. (⅔ natural size.)

Sept. 6.—Patient more conscious and is commencing to be rational. Sept. 9.—Further improvement; quite conscious and rational now. Fungus seems to be clearing up. Several small loose superficial pieces of bone picked out. Sept. 15.—Fungus now the size of small lemon; surface somewhat cleaner, but there is considerable thick yellow pus oozing up from around its sides. *X*-ray taken to-day shows very extensive depressed and bursting fracture, and large metal foreign body about 3 in. inside the right occipital lobe (*Fig.* 18).

Operation. — Novocain. Tripod incisions. Several large loose bone fragments removed. Pus coming from all directions underneath this fragmented bone area. Dura disclosed, widely opened, with a well-marked hernia protruding not only through the original wound but coming out through a long rent posteriorly. At lower end of hernia a track was found leading deeply into occipital lobe, and through it pus was coming freely. At bottom of track the foreign body was easily palpable and was removed with forceps (*Fig.* 19). It lay in an abscess cavity, and its extraction was followed by evacuation of several ounces of yellow creamy pus. Cigarette drain left down to the cavity. Partial closure.

Sept. 25.—Cultures from wound have shown streptococcus and a feeble growth of *B. Welchii*. Since operation patient has run an irregular temperature reaching 103° to 104°, but this has been subsiding during past few days. Fungus has remained the same size, drainage has been much lessened and surface of hernia has begun to granulate. Drain removed fourth day after operation. Sept. 29.—Temperature again elevated, and signs of consolidation in patient's left lung since last note. Hernia diminished in size and granulating nicely. Death to-day with all the clinical signs of a pneumonia.

FIG. 20.—*Case* 31. Section through wound; showing healing abscess track.

Autopsy.—Brain showed a well-drained and healing track leading from fungus down to former abscess cavity from which foreign body was removed (*Fig.* 20). Very slight cloudy exudate over base; the rest of brain appeared normal. Both lungs show diffuse bronchopneumonia, with consolidation of left lower lobe.

Other Fatal Cases.

Case 32.—Pte. C. M. Admitted gen. hosp., Sept. 29, 1918.

On Admission.—Patient in very poor general condition. Semi-conscious; right hemiplegia and apparently complete aphasia. Large open wound over left parieto-occipital region, with masses of gassy-smelling brain extruding. *X*-ray shows extensive depressed fracture, with many indriven bone fragments and two small foreign bodies.

Operation.—Novocain. Wound excised and depressed area removed in fragments. Dura widely perforated. Much spontaneous extrusion of disorganized brain and clots. Tension was so great that very little reduction could be secured by continued suction of the track through catheter. Partial closure.

Sept. 30.—Culture shows *B. Welchii* and *S. aureus*. No appreciable change in condition since operation. Death, with rising pulse and respiration, at 1.30 a.m. to-day.

Case 33.—Pte. T. R. Admitted to gen. hosp., Sept. 4, 1918.

On Admission.—Drowsy; semi-conscious; disoriented. Marked retraction of head. Neck very stiff. Left face and arm paralyzed. Left leg weaker than right. Small penetrating wound 3 in. above tip of right ear. *X*-ray shows foreign body in right temporo-occipital region.

Operation.—Sept. 5. Novocain. Tripod incisions. Area of cranial perforation removed *en bloc* (*Fig.* 21). Dural perforation over corresponding area. Foreign body removed at depth of 2½ in. to 3 in. below surface of dura. Track cleaned by suction through catheter. Partial closure.

Sept. 10.—Cultures from wound show *B. Welchii*. Patient has shown no improvement since operation. Retraction of neck has continued, and patient is entirely irrational and semi-conscious. Death at 11.0 a.m. to-day.

Autopsy showed large abscess cavity occupying nearly the entire right temporal lobe and part of right occipital. Rest of brain apparently normal.

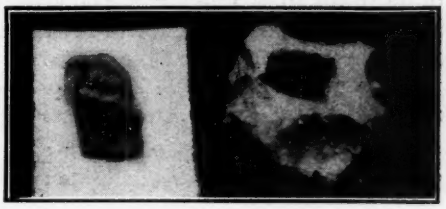


FIG. 21.—*Case* 33. Foreign body and portion of bone removed at operation (⅔ natural size).

Case 34.—Pte. G. P. Admitted gen. hosp., July 1, 1918, about 3 a.m. Patient was a victim of the bombing raid which occurred an hour and a half previously.

On Admission. — Examination shows patient entirely unconscious, with stertorous breathing of Cheyne-Stokes type. Pulse slow, 48 to 56. Pupils equal and dilated, without reaction to light. Two apparently penetrating wounds over left parieto-temporal region. No *x*-ray obtainable.

Operation.—3.45 a.m. No anæsthetic. Both wounds excised and connected with curved incision, thus turning down a flap over the injured area. Numerous linear fracture lines disclosed, running towards the base and also forward into the greater wing of sphenoid. One large piece of squamous portion of temporal bone 5 by 6 cms. in two diameters was found perfectly loose and elevated, and was easily extracted with forceps. Further loose pieces were removed around this. Dura extremely tense and discoloured. Two perforations corresponding to the two penetrating wounds of the skull. Dura incised, connecting the two perforations. Immediately large amounts of subdural clots were spontaneously evacuated, as well as much disorganized tissue. By this means the intracranial tension was greatly reduced, and the patient's breathing and pulse became distinctly better. No attempt made to find foreign bodies. Closure with rubber-tissue drain.

July 2.—Patient showed temporary improvement after operation, but became worse again this morning, and finally died at 1.45 p.m.

Autopsy showed the extensive fracture noted during life, with two tracks leading through the dura and deeply into the brain substance. Anterior track led into the left lateral ventricle, which was full of blood-clot. Posterior track led upward, crossing the mid-line and ending in the right occipital lobe. Extensive destruction along both tracks. One small foreign body at end of each track.

Group VI.—WOUNDS WITH EITHER BONE FRAGMENTS OR METALLIC FOREIGN BODIES ENTERING OR PASSING THROUGH ONE OR BOTH OF THE CEREBRAL VENTRICLES.

It is interesting to find nearly as many certified examples of ventricular involvement in this series as the number of cases in the preceding group, namely 14. That the expectancy of life, however, is far less in a wound of this character has been pointed out already by Cushing and others. Of the total 14 there were 8 deaths, a mortality of 57·1 per cent. This figure is 16 per cent less than that given by Cushing in his C.C.S. series. The only obvious explanation is that many cases which would fall into this group die before they reach base hospitals, or at least before they can be operated upon after arrival. Of the cases represented here, the 6 which recovered were operated upon thirty to thirty-six hours on an average after receiving their wounds ; the 8 which died, after an interval of fifty-six hours. Of the survivors, 2 weathered gas-bacillus infections, while in 6 of the 8 fatalities a culture of this organism was obtained.

There are several features which are worth mentioning in speaking of the group as a whole. The missiles causing the injury varied in size from 2 grms. to 46·6 grms., the latter being the largest metallic body removed in the entire series from any recovered case.

Certain operative measures will be further detailed later ; but it may be said here that in 11 out of the 14 cases the wound was left wide open directly over the dural perforation and track leading to the ventricle. It would seem, therefore, that such an open drainage of the cerebral ventricle is indicated just as strongly as is the same process in other tissues, at least in cases coming to the base with infection well started. The cerebrospinal fluid leak, which may continue several hours or perhaps a day or two, in such cases acts only in the benign capacity of carrying out the infecting organisms.

Another notable thing about these ventricular cases is the temperature chart. It is characterized by a series of very wide excursions, which are most marked in the early part of the post-operative course, but often continue for a long time after the patient seems quite well and is making a good recovery. An example of such a case is given herewith (*Fig.* 23), and others will be seen in subsequent records. This case is also noteworthy from the fact that a magnet extraction of the missile was at first attempted, but it had to be removed finally with forceps. Upon examination it proved to be a piece of lead shrapnel ball (*Fig.* 22).

Case 35.—Pte. F. M. Admitted field ambulance, Aug. 23, 1918 : " Gunshot wound of head." Casualty clearing station same date : " Shell wound of head ; one foreign body removed from scalp. Other wound penetrating (?)." Gen. hosp., Aug. 24.

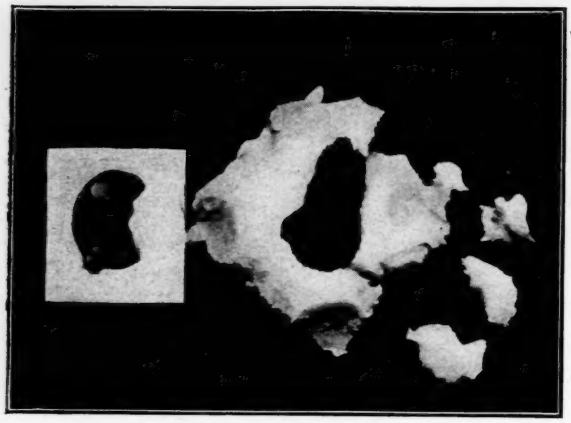


FIG. 22.—*Case* 35. Foreign body, block of bone, and indriven fragments removed at operation.

History. — Remembers little about injury. Says he was stunned, but eventually crawled into shell-hole and was brought out on stretcher.

Examination.—Patient very drowsy and wandering in mind. Complains of headache. No paralysis made out. Pupils equal and react. Deep reflexes slightly increased on left. Wounds : (1) Superficial laceration just above right ear ; (2) Probably penetrating wound about 2 in. behind and somewhat upward from first wound. *X*-ray shows depressed fracture at the site of posterior wound, with indriven bone fragments and an intracranial metallic foreign body.

Operation.—Novocain. Tripod incisions from posterior wound, and one of these incisions carried forward to anterior wound, which was found to be superficial. The area of depressed fracture around the posterior wound was exposed as usual and removed *en bloc* (*Fig.* 22). Dura found to be very tense, with considerable extrusion of brain matter through the dural perforation, which was about 1 cm. in each of two diameters. Catheter

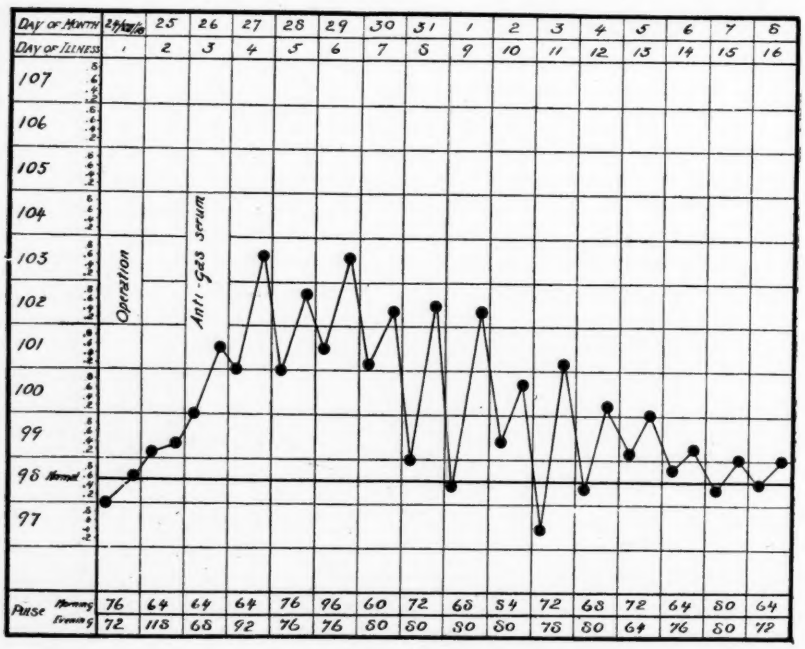


FIG. 23.—*Case* 35. Temperature chart.

introduced into track, and several indriven bone fragments palpated and removed; moderate amount of disorganized brain and clot sucked out.

At the bottom of the track at a depth of about 4 cm. a resistance was felt which was taken to be the foreign body. Three attempts to extract it by means of magnet were without success. Forceps then introduced and foreign body removed very easily. Its removal was followed by a gush of discoloured cerebrospinal fluid, evidently coming from the ventricle. The foreign body, on examination, proved to be a piece of lead shrapnel ball, thus explaining the magnet's failure. Partial closure of wound, leaving opening over place corresponding with dural perforation.

FIG. 24.—*Case* 35. Wound at time of discharge to England.

Aug. 26.—Patient better, but still apparently irrational and wandering. Cultures from wound show an anaerobic diplococcus. Hernia under skin flaps bulging moderately, so lumbar puncture was performed and an excess of blood-stained fluid under increased pressure withdrawn.

Aug. 30.—Patient much better clinically, though running an intermittent temperature from 99° to 102·5° (*Fig.* 23). Headache gone; is sitting up in bed; feeding himself, and appears normal mentally in every way. Fungus not increased in size. Sept: 8.—Fungus entirely subsided, leaving level granulating area. Temperature normal for past three or four days. Sept. 15.—Wound clean and healing rapidly (*Fig.* 24). Patient doing well. No neurological signs or symptoms. Evacuated to England.

Subsequent Report.—Oct. 9, London.—Wound healing well. No motor, sensory, or visual disturbance; no aphasia. Mental state satisfactory. Discharged, probably fit for reclassification later.

In the above case the foreign body had apparently barely entered the ventricle. In the record given next, it will be seen that the metallic fragment had actually traversed it. This patient, too, was one of those who recovered from a gas-bacillus infection.

Case 36.—Pte. F. T. M. Admitted field ambulance, Oct. 14, 1918: "Shell wound of forehead." Casualty clearing station, same date: "Bullet wound left temporal region. Doubtful penetration of skull." Gen. hosp., Oct, 15.

On Admission.—Patient very dull, and can remember nothing about his injury. Entirely disoriented. Apparently some sensory and motor aphasia. Right face slightly weak and hypæsthetic. Right arm weaker than left, and also has certain amount of sensory loss. No hemianopsia made out. Wound small and probably penetrating, in left subtemporal region, 1 in. above tragus. *X*-ray shows depressed fracture at site of wound, with intracranial metallic foreign body probably in left post-parietal region.

Operation.—Novocain. Wound excised and incisions extended vertically upward and downward as in decompression. Small punched-out hole disclosed low down in temporal region. Area around this hole removed by burr opening above it and piecemeal removal of bone by rongeurs, as it was too low down to encircle in the usual manner. Extremely troublesome bleeding from two large meningeal branches which had been torn across by fracture lines. Eventually muscle was used with success for hæmostasis. Dura found bulging and very tense, with a small perforation corresponding to the punched-out wound in bone. Upon introducing a catheter through this perforation, large amounts of dark semi-fluid clot were immediately evacuated, and much more was sucked out in the usual manner. Track led posteriorly and inwards through the left lateral ventricle to a depth of about 3½ in. At the bottom a resistance was felt which was at first taken to be the foreign body; but after two unsuccessful attempts with a magnet, this surmise was found to be incorrect, and further attempts were deemed unwise. Fairly complete closure, leaving rubber-tissue drain down to dura.

Oct. 20.—Cultures from wound show a bacillus resembling *B. Welchii*, but without its gross reaction. Nov. 4.—Uneventful convalescence. Wound has cleaned up nicely, and there is now a small granulating area at its former site. Neurological examination entirely negative. Evacuated to England. No subsequent reports.

Among all the patients in the entire series, the one whose record is given next was perhaps the nearest to death. The missile was small, about the size of a pea. It entered

the skull in the right subtemporal region, just anterior to the upper attachment of the pinna. From here its course was very slightly upward, but nearly straight through the brain, traversing both the right and left lateral ventricles as noted at operation, and lodging in the left hemisphere about one inch inside the skull. Later, by making careful cranial measurements, as well as a drawing from the *x*-ray plate, Lieut.-Colonel Gordon Holmes demonstrated to me that the missile must have passed also through the third ventricle. The bloody contents of both lateral ventricles were evacuated by means of suction with a catheter at the time of operation. There was temporary improvement, but next day the patient was deeply cyanotic, with very rapid breathing and fast weak pulse. He was thought to be surely dying, but his condition unaccountably improved during the day, and he eventually made a very slow but most satisfactory recovery. The detailed record is given below.

Case 37.—Pte. J. M. Admitted field ambulance, Aug. 28, 1918: "Gunshot wound of head, penetrating." Casualty clearing station, same date: no note. Gen. hosp., Aug. 29.

On Admission.—Patient semi-conscious; very rapid breathing; pulse full but rapid. Both arms and legs can be moved. No facial weakness made out. Reflexes not elicited at either knee

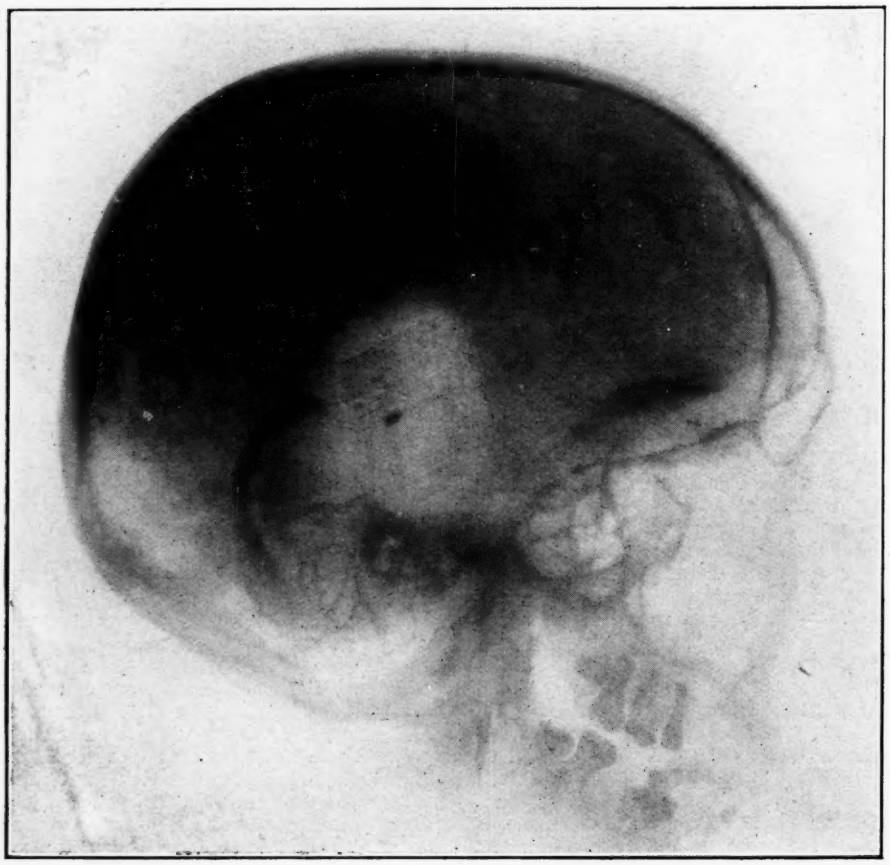


FIG. 25.—*Case* 37. *X*-ray showing position of foreign body.

or ankle. A small penetrating wound in right subtemporal region just anterior to and slightly above tragus. *X*-ray shows foreign body the size of a pea in the opposite hemisphere (*Fig.* 25).

Operation.—Novocain. Vertical incision as for decompression, excising wound. Small round hole in skull disclosed. Fairly wide circular area of bone removed around this pole by burr opening and rongeurs. The catheter was introduced into the track through the dural opening as usual, and considerable amounts of clot and disorganized brain were removed by suction. The dural

tension had been very great at first, but the evacuation of the disorganized clot, especially, relieved this to some extent. As the catheter was introduced through the track the right ventricle was first entered and its fluid contents sucked out. Passing the catheter further along the track at a depth of about 5 in. the left ventricle was found to have been traversed by the missile also, and again the bloody ventricular contents were sucked out through catheter. Patient's breathing and general condition seemed to improve directly the blood was removed from the ventricles. Wound closed in layers without drainage.

Aug. 30.—Patient cyanotic this morning, with rapid breathing and fast weak pulse. Thought to be moribund, and screens were placed round the bed. He remained in this condition all day, but toward night there began to be slight improvement, with stronger pulse and better respiration. Aug. 31.—Responds to questions slightly this morning. Neck, however, is stiff and retracted. Ten c.c. of fairly clear fluid, not under increased pressure, were withdrawn by lumbar puncture. Sept. 3.—No great change during last two days. Pulse fair, but still quite rapid; last night, however, temperature went up to 103°, the breathing again becoming laboured. (*Fig.* 26.) Lungs show signs of commencing bronchopneumonia at bases. Put up on bed-rest. Cultures from previous lumbar puncture are negative.

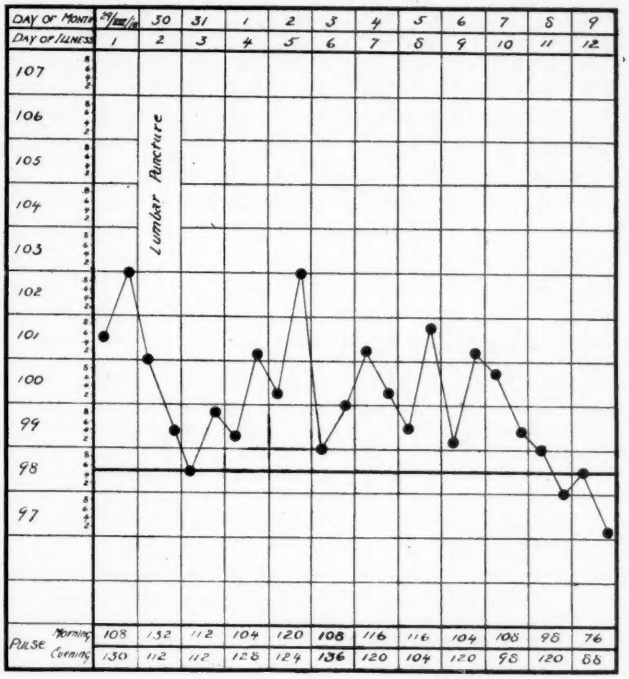


FIG. 26.—*Case* 37. Temperature chart.

Sept. 8.—Temperature has dropped to normal to-day after a gradual decline. Patient quite responsive; says he feels very well. Has been kept on bed-rest since last note. Can see very little, and has a peculiar vacant stare as he sits in bed. Left pupil larger than right. He will not follow the examiner's fingers with his eyes, but says he can see them, and names correctly the number of fingers held up, after some hesitation. He cannot, however, name articles which are held up before him, and looks round vacantly when asked to fix upon an object held before his eyes. He either cannot or will not look up, down, or to the right, but does turn his eyes to the left slightly. Examination of fundi negative.

FIG. 27.—*Case* 37. Showing wound entirely healed at time of discharge to England.

Sept. 14.—Beginning to see things better now. Will follow the finger, and count fingers accurately. Moves eyes to right and left, but cannot look upwards well, and is unable to look downwards at all. Sept. 16.—Rough examination of visual fields shows questionable defect in the left eye.

Oct. 4.—Convalescence uneventful since last note. Wound healed (*Fig.* 27). Patient almost normal mentally. Eye movements improving. Can look upwards fairly well, but although now able to look down, always converges in doing so. Can recognize objects about the ward, but is unable to read even large print. Left arm very unsteady, with intention tremor. Evacuated to England.

Subsequent Report.—Oct. 30, 1918, London.—Wound healed completely. No motor disturbance. Left arm and leg still show inco-ordination. Localization poor. No astereognosis. Left hemianopsia. No aphasia. Mental state perfectly good. Transferred to a hospital in Scotland.

Although one always watches with some astonishment the recovery of ventricular cases even when the offending missile has been a small one, this sensation is trebly increased when observing the almost mild convalescence of such a case as is given in the next record. In the first place, the piece of shell removed from this patient's brain was the largest of any in the series of those who recovered, its weight being 46·6 grms. Its measurement in three planes was 5 by 2 by 1·5 cms. That the missile entered the skull 'end on' undoubtedly prevented an immediate fatality. That the man was of large robust frame and in perfect physical condition goes far toward accounting for the fact that he not only weathered the original shock but also withstood the ventricular penetration as well as a gas-bacillus infection. The subsequent letters and reports given in connection with the case will show how complete has been his return of function.

This case was among those which were given a considerable amount of anti-gas-gangrene serum, both intramuscularly and also by local applications to the hernia cerebri. More will be said of this treatment subsequently; but it may be noted here that at the time of operation, 10 c.c. of the serum was actually poured into the patient's brain, along the track leading directly down to the ventricle from which the missile had been extracted.

Case 38.—Dvr. G. H. G.—Admitted field ambulance, April 29, 1918: "Shell wound head." Casualty clearing station, same date: no note. Gen. hosp., April 30.

History.—Says he was dazed after injury but not unconscious; did not walk afterwards; memory for past events not entirely clear.

On Admission.—Patient conscious but very drowsy. Mentality upset, but is fairly rational, though inclined to be talkative. Right pupil larger than left; both react to light and accommodation. No nystagmus. Right homonymous hemianopsia. Slight numbness, hypæsthesia, and

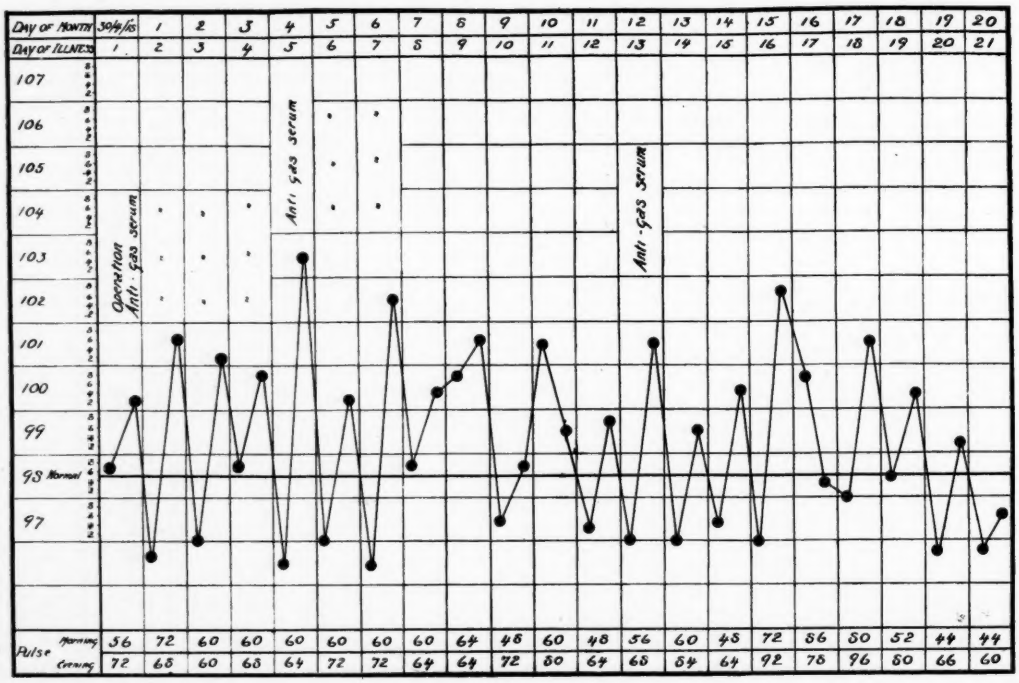


FIG. 28.—*Case* 38. Temperature chart.

weakness of right arm. Complete astereognosis and loss of muscle sense on the right. Wound: lacerated and penetrating hole over left parietal-occipital region fairly high near the vertex; brain extruding. Wound smells of gas infection. Smears from wound show *B. Welchii*. *X*-ray: depressed fracture at site of wound, with very large oblong intracranial foreign body deep in left hemisphere.

Operation.—Novocain. Wound excised. Tripod extensions. Punched hole in skull disclosed about 1 by 1 in. in two diameters. Much disorganized brain and some small bone frag-

ments protruding through this hole. Area around the penetration removed piecemeal. Large hole in dura corresponding to that in the bone. Indriven bone fragments removed and track sucked out by catheter. The upper end of the foreign body was easily palpated about 2 cms. below the dura. It was grasped with forceps and gently extracted; removal was followed by a gush of bloody cerebrospinal fluid from the ventricle, the cavity of which was plainly visible after the removal of the foreign body, which proved to be a very large piece of shell-casing, roughly oblong in shape and weighing 46·6 grms. After its removal 10 c.c. of anti-gas-gangrene serum was poured into the track, and the wound then closed tightly without drainage. Ten c.c. of anti-gas-gangrene serum was also given intramuscularly directly after operation.

May 2.—Cultures from wound show strong growth of *B. Welchii*. Wound bulging somewhat to-day; therefore opened up and a moderate-sized hernia disclosed. Pledgets of cotton soaked in anti-gas-gangrene serum applied locally to the hernia, and intramuscular treatment also continued. May 7.—Hernia not increasing. Repeated cultures continue to show *B. Welchii*. Anti-gas-gangrene serum treatment continued, both locally to hernia and intramuscularly. Patient running a fluctuating temperature from subnormal to 103° (*Fig.* 28). General condition quite good. Moderate headache; hemianopsia persists.

May 17.—Up to yesterday the hernia remained about the same in size, although apparently getting somewhat cleaner every day. On doing the dressing to-day it was found that the hernia had entirely collapsed and receded, leaving in its place a cavity about 2 in. in depth leading directly inwards into the left occipital lobe. There has been no special change in the patient's condition except for a general daily improvement. May 29.—The cavity still persists, and has been irrigated with salt solution every other day. For the past twenty-four hours the patient has had the foot of his bed elevated, and cavity has become slightly smaller. June 2.—Cavity almost entirely disappeared, leaving only a narrow sinus. Practically no discharge. General condition excellent. Very little difference in arms now. Right visual field coming back. June 10.—No demonstrable visual defect now. June 20.—Sinus entirely closed; no discharge. Patient sitting up in bed. June 25.—Granulating wound, surface clean, and epithelium covering over rapidly. Pupils equal. Strength of arms nearly equal. No hypæsthesia, astereognosis, or loss of muscle sense on the right. Mentality normal, with the exception of slight memory defects. Evacuated to England.

Subsequent Reports.—Aug. 21, 1918, London.—Wound completely healed. No motor, sensory, or visual disturbance. Mental state clear, except that patient complains of forgetfulness. Discharged to go to an Australian Medical Board.

By letter from patient, *Oct.* 28, 1918.—"I am thankful to say that I am practically as fit as the day I was born, except that my right arm is slightly weaker than its fellow. I have been up for my final Board, and am marked C 2, or permanently unfit for active service."

The two other recoveries in this group show no unusual features, and therefore need not be dealt with in detail.

The Fatal Cases.—As mentioned previously, 6 of the 8 cases which died gave a culture of the gas bacillus from the cerebral tissue, showing once more the very serious nature of this organism in brain cases.

The detailed clinical records of three of the fatalities show features of more than ordinary interest. The first is an example of double ventricular involvement, with incomplete removal of the bone fragments, leading eventually to purulent ventriculitis, and death forty-four days after injury. Possibly in this instance a secondary operation, with reopening of the track through the hernia and drainage of the left ventricle, at least, might have been of some avail. Another interesting clinical symptom was the continued vomiting, without nausea, apparently a ventricular phenomenon. While being fed with a stomach tube, however, this patient retained liquid nourishment for many days.

Case 39.—Pte. F. H. H.—Admitted field ambulance, Aug. 27, 1918: "Gunshot wound of head; and left thigh." Casualty clearing station same date: "Gunshot wound of head; condition good; somewhat irrational. No focal symptoms." Gen. hosp., Aug. 28.

On Admission.—Patient irrational; partially aphasic. Very drowsy, and answers only vaguely, in monosyllables. No paralysis or sensory loss made out. Reflexes normal. No memory for past events.

Three-inch gutter wound, dirty, over left frontoparietal region, with brain extruding. *X*-ray not taken.

Operation.—Novocain. Wound excised; area around large depressed fracture removed piecemeal. Many superficial and deeply indriven bone fragments palpated with catheter and removed with forceps. Much disorganized brain and clots sucked out of track, at the bottom of which a large piece of inner table was palpated with catheter and extracted. This piece proved to have been in the ventricle, as its removal was followed by the customary gush of blood-stained ventricular fluid. Partial closure of wound.

Aug. 30.—Cultures from wound show *B. Welchii* and short-chain streptococcus. There is a hernia at the site of the wound which is flush with the scalp. Sept 3.—During the past two days temperature elevated to between 102° and 104°, but patient seems clinically better than temperature indicates. His very passive mental state, however, persists. His facial expression is almost mask-like, and his answers to questions seem absolutely mechanical and expressionless. Fungus increasing in size. Cultures again show *B. Welchii* and short-chain streptococcus. Anti-gas-gangrene serum applied directly to hernia. Sept. 5.—Hernia still larger. Temperature running between 104° and 105·5°. There is now a slight weakness of right face and arm.

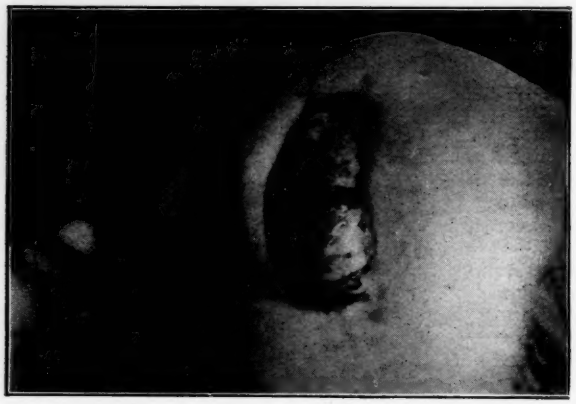


FIG. 29.—*Case* 29. Wound showing granulating area left by collapse of hernia.

Sept. 23.—General condition appears about the same, but temperature on the whole slightly lower, though irregular. There has been irregular vomiting, without nausea, several times a day during the past two weeks. On changing the dressing to-day it was found that the hernia had entirely collapsed, leaving a granulating area depressed below the scalp edge.

Sept. 30.—Patient has had persistent vomiting for past week; retains nothing.

Oct. 11.—Vomiting has continued, but he has managed to retain feedings given by stomach tube after previous gastric lavage. He has continued to lose weight, however, and his general mental condition has sunk to a very low state. He still understands what is said to him, but his responses are limited to nodding of the head. There has been no protrusion of the wound area, which has remained flush with the scalp or slightly depressed (*Fig.* 29). No stiffness of the neck, positive Kernig, or other signs of meningitis. Fundi have been normal throughout. This general sinking ended in death this morning at 8.25.

Autopsy.—The granulating wound area at the site of the previous hernia connected through a track with the anterior end of the left lateral ventricle. This ventricle was very much dilated and full of a thin purulent fluid. Ventricular wall was covered with a fibrinopurulent exudate, and this exudate also surrounded the anterior part of the choroid plexus. Several small pieces of bone were found embedded in the mesial wall of this ventricle. The track then led across into the anterior end of the right lateral ventricle, and here three or four small pieces of bone were found. This ventricle was also greatly dilated and full of the same thin purulent fluid.

The anterior part of the left frontal lobe was softened and partially disorganized, but otherwise the surface of the cerebral hemispheres appeared perfectly smooth and normal. There was a slight clouding of the arachnoid over the base. Cerebrum, pons, and medulla normal. Contents of the abdominal viscera negative.

The second example is one of the rare instances of a purely staphylococcal meningitis. It is also a case of magnet extraction of the foreign body with complete excision of the area of fracture *en bloc*, as shown in *Fig.* 30. One would have expected this to be a very favourable type of case.

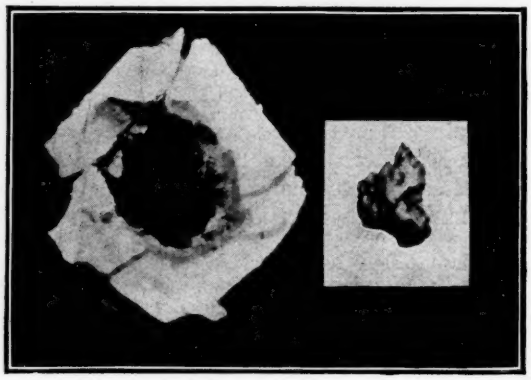


FIG. 30.—*Case* 40. Foreign body and under-surface of block of bone removed at operation.

Case 40.—Pte. E. M. M. Admitted gen. hosp. Aug. 27, 1918. Wounded Aug. 26.

On Admission.—Paresis left face and arm; left leg weaker than right, with exaggerated knee-jerks; no clonus. Patient disoriented and apparently irrational. Large, penetrating wound over right parietal region; brain extruding. *X*-ray showed depressed fracture, with foreign body about 2 in. intracranially.

Operation.—Novocain. Wound excised and area of depressed fracture removed *en bloc* (*Fig.* 30). Round punched-out hole in dura, with considerable herniation through it. Indriven bone fragments removed; track sucked out with catheter; foreign body extracted with magnet. Partial closure.

Aug. 29.—First dressing; hernia flush with skin edge; patient having considerable headache. Culture from wound showed anaerobic staphylococcus. Aug. 31.—Headache has increased markedly. Hernia now bulging considerably, and patient has become semi-conscious, with rising temperature. Died at 3 a.m.

Autopsy showed that the track passed backward from the wound, involving the right ventricle, which was somewhat dilated and contained a little blood-clot. Considerable disorganization of brain around track. No bone fragments found at autopsy. The base showed slight purulent exudate. Three solitary tubercles, two in the right frontal lobe and one in the left occipital lobe. They were small, with calcified contents, and probably played no part in causing patient's death.

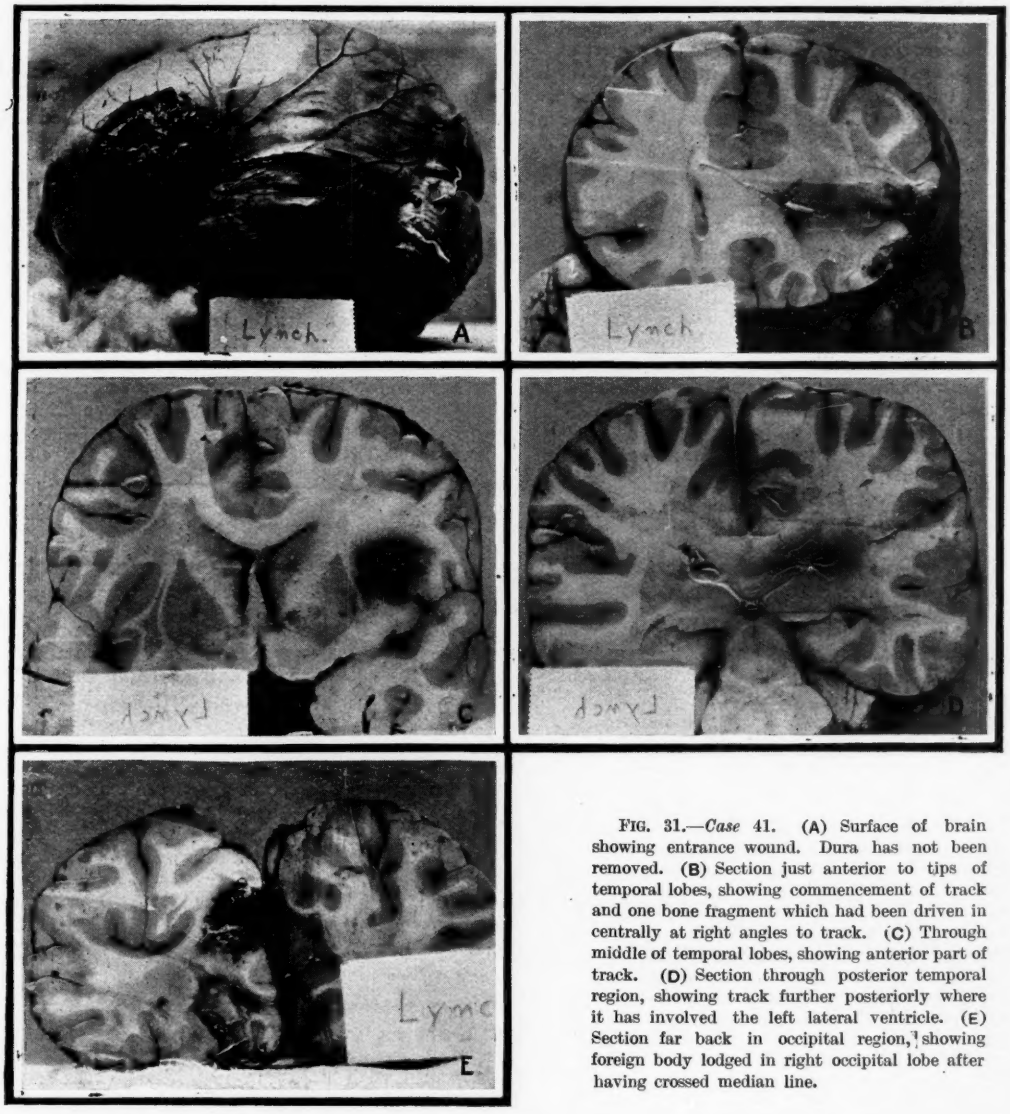


FIG. 31.—*Case* 41. (A) Surface of brain showing entrance wound. Dura has not been removed. (B) Section just anterior to tips of temporal lobes, showing commencement of track and one bone fragment which had been driven in centrally at right angles to track. (C) Through middle of temporal lobes, showing anterior part of track. (D) Section through posterior temporal region, showing track further posteriorly where it has involved the left lateral ventricle. (E) Section far back in occipital region, showing foreign body lodged in right occipital lobe after having crossed median line.

A third case may be cited, as showing the great shock effects of even a small missile, which traversed not only the ventricle, but nearly the entire length of the left hemisphere as well. As shown in *Fig.* 31 E, the foreign body finally crossed the mid-line, and lay just within the mesial surface of the right occipital lobe.

***Case* 41.—Pte. J. L. Admitted gen. hosp., Sept. 23, 1918. Wounded thirty-six hours previously.**

On Admission.—Patient semi-conscious, with incomplete aphasia. Right hemiplegia. Large penetrating hole of left frontal region, with brain extruding. *X*-ray showed fracture at site of wound, with foreign body near mid-line in occipital region.

Operation.—Novocain. Wound excised; tripod extensions. Area around hole in skull removed. Much spontaneous extrusion of disorganized brain and clots through dural perforation. Catheter introduced into track for distance of 6 in., and much more pulped tissue and clots sucked out. Track passed through apparently the entire length of the left lateral ventricle, which was emptied of its bloody contents through the catheter. No attempt made to extract foreign body, which was too far posterior to be obtainable by the magnet. Hernia entirely reduced at end of operation. Partial closure.

Sept. 25.—Cultures from wound showed an anaerobic short-chain streptococcus and a staphylococcus. After relative improvement for first twelve hours after operation, patient's pulse and respiration became rapid, and he died at 2.30 a.m.

Autopsy.—Surface of brain and of base normal. Track of missile passed posteriorly through entire length of left hemisphere, including lateral ventricle, as noted at operation, and foreign body found lying just within medial surface of tip of the right occipital lobe, having crossed the mid-line at this point (*Fig.* 31). There was only slight destruction of tissue around the track.

Short records of the remaining 5 fatalities are appended. All these were gas-bacillus infections, and came down with stinking fungating wounds. They were operated upon simply to give them the faint chance of benefit from surgical cleansing.

Case 42.—Pte. E. C. Admitted gen. hosp., Aug. 27, 1918. Wounded two days previously.

On Admission.—Patient semi-conscious. Complete aphasia, right hemiplegia and right homonymous hemianopsia. Three-inch dirty gutter wound of the left parieto-occipital region; brain extruding.

Operation.—Novocain. Wound excised. Area of depressed fracture removed; many indriven bone fragments extracted. Track cleaned out by suction with catheter. Dichloramine-T; partial closure.

Aug. 28.—Cultures from wound showed *B. Welchii*. Large hernia at site of wound treated by pledgets of cotton soaked in anti-gas-gangrene serum. Sept. 3.—Hernia extremely large; temperature elevated to between 103° and 104°. The patient gradually became less conscious. Cultures continued to show *B. Welchii*. Death at 5 a.m.

Autopsy showed marked encephalitis and great destruction of left hemisphere. Track involved the left lateral ventricle, and several small bone fragments were found post mortem which had not been obtained at operation.

Case 43.—Pte. J. M. Admitted gen. hosp., Oct. 16, 1918. Wounded two days previously.

On Admission.—Patient semi-conscious, restless, and unmanageable. Able to move both arms and legs. Questionable left hemianopsia. Large, dirty, gassy-smelling lacerated area over right occipital region; brain extruding. *X*-ray showed depressed fracture, with indriven bone fragments and several small intracranial foreign bodies.

Operation.—Ether. Wound excised and depressed area removed. Much spontaneous evacuation of infected cerebral tissue and clots through dural perforation. Catheter introduced to 3 in., and large amount of disorganized very foul-smelling tissue sucked out. Many indriven bone fragments also removed. Hernia greatly reduced. Partial closure.

Oct 18.—Cultures from wound showed *B. Welchii* and also a short-chain streptococcus. Patient has shown very little, if any, improvement since operation. Gradual sinking, and death to-day at 10.50 p.m.

Autopsy.—Extensive encephalitis of right occipital lobe, with track running forward involving right ventricle, which was filled with purulent fluid. A secondary track ran off diagonally from the first one into the left hemisphere, ending in the posterior Rolandic area in an abscess of gas infection about the size of an English walnut. Commencing basilar meningitis.

Case 44.—Pte. S. C. R. Admitted gen. hosp., Sept. 29, 1918.

On Admission.—Patient conscious, but wandering and somewhat irrational. Right homonymous hemianopsia; no other neurological signs. Penetrating wound of left occipital region; very gassy-smelling. *X*-ray showed fracture at site of wound, with foreign body, which had traversed the entire length of the hemisphere, lying in left frontal lobe.

Operation.—Novocain. Wound excised and the area of depressed fracture removed; many indriven bone fragments and much disorganized gassy-smelling brain tissue sucked out by catheter. Partial closure.

Oct. 1.—Cultures from the wound showed *B. Welchii* and streptococcus. Well-marked gassy-smelling hernia at site of wound. Temperature 103·5°. Oct. 9.—Patient had gradual downward course, becoming more drowsy each day; died at 10.0 a.m.

Autopsy showed extensive disorganization and encephalitis of left occipital lobe, with marked destruction around track leading forward to site of foreign body in frontal region. Basilar meningitis.

Case 45.—Pte. M. R. Admitted gen. hosp., Oct. 16, 1918. Wounded two days previously.

On Admission.—Patient practically unconscious; can barely be made to respond by supra-orbital pressure. Moves both legs; right arm seems weaker than left; positive Babinski on right. Marked retraction of head and positive Kernig. Small penetrating hole in left post-parietal region. *X*-ray discloses depressed fracture, with indriven bone fragments and an intracranial foreign body at a depth of 2 in. from wound of entrance.

Operation.—Novocain. Tripod incisions; area of depression removed by encircling. Marked hernia through dural perforation. Dura extremely tense. Catheter introduced into track, which ran inward and down through left lateral ventricle and beyond it, to a depth of about 4 in. Ventricle full of bloody fluid, evacuated through catheter. Large amounts of infected brain tissue sucked out. Attempt to remove foreign body by magnet unsuccessful. Partial closure.

Oct. 17.—Cultures from wound showed *B. Welchii*. Temporary improvement for twelve hours following operation, then steady and rapid decline, with death.

Autopsy.—Foreign body recovered in mid portion of right ventricle. Left ventricle found full of old blood-clot. Large amount of purulent fluid in right ventricle. Considerable destruction of left hemisphere around track, with encephalitis; no evidence of meningitis.

Case 46.—Sgt.-Major B. W.—Admitted gen. hosp., Sept. 3, 1918. Wounded two days before.

On Admission.—Patient drowsy and somewhat irrational, with aphasia. Right hemiplegia and hemihypæsthesia. Three-inch gassy-smelling gutter wound of left parietal region near vault. *X*-ray showed extensive comminuted fracture of left parieto-occipital region, with many large and small indriven bone fragments.

Operation.—Novocain. Wound excised. Thorough débridement of superficial tissues; fractured area removed piecemeal. At the medial side of the dural perforation the longitudinal sinus had been punctured by one of the bone fragments, and the hæmorrhage necessitated muscle for control. Very marked herniation through dural perforation; many indriven bone fragments removed, as well as two small foreign bodies just within the dura. Track cleaned by catheter suction. At bottom of track two large pieces of bone picked out which had penetrated the ventricle. Partial closure.

Sept. 14.—Repeated cultures have shown *B. Welchii* and *S. aureus*. Patient had gradual downward course, hernia becoming very large. Death early this morning.

Autopsy.—Left hemisphere showed great destruction both by laceration from the wound itself and also by marked encephalitis. Track extended into left lateral ventricle.

Group VII.—CRANIO-CEREBRO-FACIAL INJURIES.

Seven cases have been placed under this heading, all of them of the cranio-orbital type. They differ markedly from the cases of this group seen at a casualty clearing station, in that those which recover are of a much milder form, the fact being that many cases more severely injured have probably died either before or during transport. Of the 7, there were 4 recoveries and 3 deaths, a 42·8 per cent mortality. The operation in nearly every case consisted in the enucleation of one or both eyes, together with the removal of bone fragments where necessary.

The record of one of the more severe examples of a recovered case, with large foreign body, is as follows:—

Case 47.—Gnr. E. W. P. Patient was dressed at field ambulance and casualty clearing station; admitted to gen. hosp., Aug. 9, 1918. Wound received twenty-four to thirty-six hours earlier.

On Admission.—Patient conscious and rational; no intracranial symptoms other than severe headache. Extensive lacerated wound running from root of nose directly into right orbit, with complete destruction of right eye. *X*-ray: Large foreign body above zygoma (*Fig.* 32).

Operation.—Ether. Lacerated edges of wound excised, disclosing comminuted nasal bone. Right eyeball had been traversed by missile, and remains of the eye were therefore enucleated. Track continued inward and somewhat laterally, fracturing the inferior orbital ridge and ascending wing of zygoma. Foreign body removed. Plastic closure.

Aug. 22.—Uneventful convalescence except for moderate headache. Wound remained clean throughout. No neurological signs or symptoms. Evacuated to England. No subsequent report.

The other three cases were similar to the following, the cerebral damage probably consisting mainly in severe contusion, the greatest risk being in the exposure to a meningitis from the fracture lines communicating with either the naso-orbital or auricular cavities.

Case 48.—Pte. H. J. G. Admitted field ambulance Sept. 1, 1918: "Shell wound of head, left." Casualty clearing station, same date: "Head wound penetrating right eye." Gen. hosp., Sept. 3.

On Admission.—Patient conscious and rational. Face markedly swollen on both sides; but no fracture of jaw made out. Complete left facial palsy. One penetrating wound, at outer end of right eyelid. Right eye destroyed. Two small lacerated wounds below left ear. *X*-ray showed fracture of posterior orbital wall, with small foreign body lying just posterior to it. Also linear fracture of left posterior auricular region running through petrous portion of temporal bone.

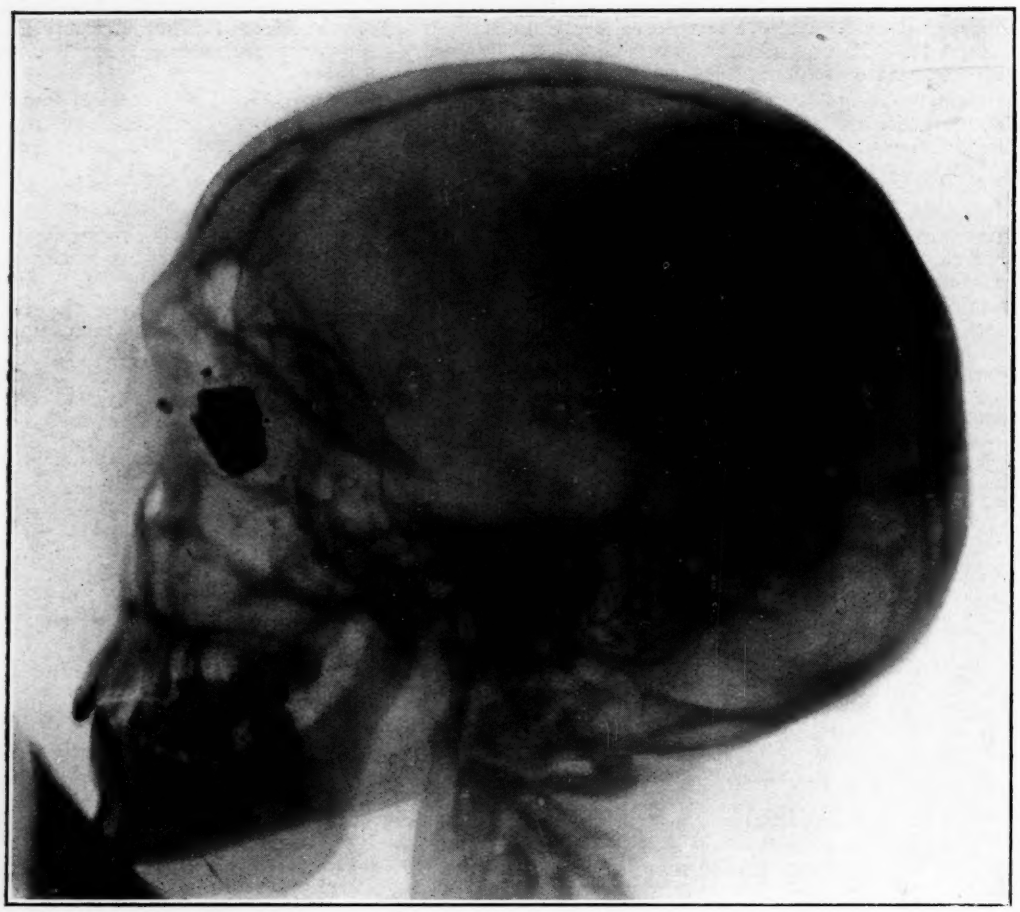


FIG. 32.—*Case* 47. Lateral *x*-ray, showing position of foreign body.

Operation.—Sept. 5. Ether, Remains of right eye enucleated, and edges of small lacerated wounds of eyelid approximated with fine silk. Posterior wounds cleaned and dressed.

Sept. 9.—Eye enucleation clean and doing well. Small wounds back of left ear also clean. Evacuated to England. No subsequent report.

The Fatal Cases.—These three cases represent the extremely severe injuries like those seen in forward areas. Their clinical records are given in full.

Case 49.—Pte. G. C. Admitted gen. hosp., Oct. 16, 1918. Wound received twenty-four to thirty-six hours previously.

On Admission.—Large gaping wound on left forehead running down into the left eye; end of machine-gun bullet protruding between closed lids of eye. Also small wound just lateral to left eye, with piece of shell-casing protruding; left eye entirely destroyed. Large masses of brain tissue escaping from the wound in forehead.

Patient conscious and rational; able to answer questions fairly well, though dull and somewhat disoriented. No paralysis or other intracranial symptoms other than those noted.

Operation.—Ether. Remains of left eye enucleated. Both protruding foreign bodies mentioned above easily removed. Careful débridement of wound and subcutaneous tissues; zygoma found to be comminuted, and fragments removed. The wound in the cheek found to connect with wound in forehead, as did also the wound through the eye.

Posterior wall of the orbit was extensively fractured, and just lateral to the left frontal sinus the skull was penetrated, and it was from this hole that the cerebral tissue was extruding. The loose disorganized brain tissue was washed away as well as possible, and some small pieces of bone picked out from inside the dural penetration. Wound partially closed, leaving drain through small cheek wound and another at the upper end of the forehead.

Oct. 22.—Patient did quite well for first two or three days after operation, but developed profuse cerebrospinal fluid leak. Gradually became unconscious for forty-eight hours before death at 2 p.m.

Autopsy.—Extensive comminution of frontal bone at site of injury, with long linear fracture running back across left temporal and occipital regions as far as occipital suture. This fracture had torn through several branches of meningeal artery, and the hæmorrhage caused thereby had formed a considerable extradural clot. The dura at the tip of the left frontal lobe where the penetration had occurred was torn over a much wider area than had been surmised at operation, and the track ran directly inwards into the left lateral ventricle. Both this ventricle and the right were tremendously dilated, and filled with a purulent fluid. Over the walls of both ventricles there lay a fibrino-purulent exudate, and this exudate also enclosed the choroid plexus of both sides. The pus extended down to the third and fourth ventricles into the spinal canal. There was a very slight greyish film over the base, but meningitis was not marked. In the left ventricle two fairly large pieces of bone were recovered, one anteriorly, the other in the posterior horn. The surfaces of both hemispheres and of the cerebellum were normal.

Case 50.—Pte. T. M. Admitted gen. hosp., Oct. 3, 1918. Wounded four days previously.

On Admission.—Patient semi-conscious, with entire loss of memory. Apparent entrance wound of left temple, which has traversed the left eye. Lacerated deep wound of right temple extending into orbit and destroying right eye. Much brain extruding from second wound.

Operation.—Ether. Remains of both eyes enucleated. From the cavity of the right orbit there extends a large excavation communicating with the right frontal lobe and with the large wound of the right temple. Large masses of disorganized brain washed out of this cavity, and many comminuted bone fragments picked out.

Patient was in exceedingly poor condition before operation, and showed no change for the better afterwards. Death at 8.0 the same evening.

Case 51.—Pte. G. H. R. Admitted gen. hosp., Sept. 21, 1918; wounded three days before.

On Admission.—Patient conscious and rational; no intracranial symptoms. Complete peripheral left facial paralysis. Through-and-through wound from left eyebrow to left side of neck, 1½ in. below the mastoid, traversing left eye; also two wounds of left shoulder, probably through-and-through.

Operation.—Sept. 22. Ether. Enucleation of remnants of left eye. Wound of neck excised and rubber-tissue drain introduced. There is a cerebrospinal fluid leak from left ear. Wounds of shoulder excised and sutured.

Sept. 25.—Patient wandering in mind, and restless. Neck stiff. Cerebrospinal fluid leak has continued. Sept. 30.—Patient has continued to go down hill, remaining irrational, and died this morning at one o'clock.

Group VIII.—WOUNDS TRAVERSING THE CRANIAL CHAMBER.

It is rather surprising to find that 10 patients having through-and-through wounds of the head lived long enough to come to operation at a base hospital. There were but two survivors from this number, a mortality of 80 per cent. The average time between the reception of the injury and their arrival at the base was forty-eight to fifty-six hours. Every case in this group was admitted in either an unconscious or semi-conscious state, and in many instances large doses of a narcotic were necessary to render them at all manageable.

At least 7 of the cases were of the type usually considered hopeless and therefore inoperable, but were given the chance of benefit from a surgical débridement under novocain. Of these, 1 made an excellent recovery, thus compensating for the many hours of useless operating spent on the remaining 6. Two other patients lived for considerable periods after operation, one dying on the sixteenth day from a sudden basilar meningitis, and the other on the thirty-eighth day from a purulent ventriculitis. Of the fatal cases, 3 showed positive cultures of *B. Welchii*, but the most frequent cause of death was undoubtedly the extreme grade of cerebral laceration, hæmorrhage, and attendant shock.

The clinical records of both recovered patients are appended. The first is an example of both craniofacial and through-and-through wound, the exit being directly through the right eye.

Case 52.—Pte. C. H. D. Admitted casualty clearing station, Aug. 8, 1918: "Penetrating wound eyeball." Gen. hosp., Aug. 9.

On Admission.—Patient somewhat irrational; restless and drowsy. No other intracranial symptoms. Through-and-through wound from right post-auricular region, the exit being through the right eye. *X*-ray shows small hole in skull at entrance, with extensive linear fractures radiating over right temporoparietal region.

Aug. 12.—Patient's wounds have been re-dressed each day. He is still restless and irrational.

Operation.—Ether. Remaining fragments of right eye eviscerated. Track leads back into brain from posterior wall of the orbit, which is comminuted. One large bone fragment removed. Following this removal there was a moderate extrusion of cortical substance through the track at the posterior part of the orbit. Posterior wound not touched.

Aug. 22.—Convalescence uneventful. Mental condition has practically entirely cleared up now, and he seems quite normal. Both wounds are perfectly clean. No hernia cerebri. Evacuated to England.

Subsequent Report.—Harefield, Middlesex, Sept. 25.—Wound healed; no motor or sensory disturbance; no aphasia. Mental state good. Vision in left eye normal. Returning to Australia.

The second case illustrates the extreme grade of the so-called 'frontal syndrome.' This patient came down semi-conscious, about fifty-six hours after injury. At frequent intervals he would rouse up, shout out curses and obscene language, and become entirely unruly. This condition persisted several days after operation, but eventually his mental condition became practically normal, and he was a most docile and attractive patient.

Case 53.—L.-Cpl. R. T. G. Admitted field ambulance, Sept. 2, 1918: "Shell wound of head." Casualty clearing station, same date: "Penetrating wound of head. Hernia cerebri. General condition good. Evacuated under pressure." Gen. hosp., Sept. 4.

On Admission.—Patient conscious but irrational, and at times very restless, noisy, irritable, and unruly, with inhibitions entirely gone and exhibiting all the symptoms of a frontal lobe lesion. No right-sided paralysis. Through-and-through wound from right temple to left frontal region near vault. Brain extruding from exit wound. Both eyelids closed with œdema, and ecchymotic. *X*-ray shows small fracture at entrance, and extensive comminuted fracture with elevated fragments at exit.

Operation.—Novocain. Tripod incisions, with excision of wound of exit. Many large comminuted and elevated fragments removed. Large fungus disclosed. Several bleeding meningeal branches, required the employment of muscle. Catheter introduced into track in direction of entrance wound to a distance of 5 inches; very large amounts of brain and clots removed by suction. Patient quieted down somewhat at end of operation. Partial closure, leaving opening over hernia, which was greatly reduced.

FIG. 33.—*Case* 53. Exit wound at time of discharge to England.

Sept. 6.—Patient less noisy on the whole, but still bursts out at times into wild yells and obscene language. Hernia flush with scalp edge. Swelling of the face and eyelids subsiding. Culture from wound shows an anaerobic staphylococcus. Sept. 12.—General improvement, with temperature remaining normal, but patient still lapses into wild language at times. Hernia about size of English walnut.

Sept. 26.—Nearly normal mentally, though still incontinent. Hernia granulating nicely. Cultures now show both anaerobic staphylococcus and streptococcus.

Oct. 18.—Hernia level with scalp and has clean granulating surface (*Fig.* 33). Patient quite normal in every way except for continued incontinence. Evacuated to England.

The Fatal Cases.—The 2 cases which died many days after they had been operated upon are recorded next. The first is another example of pronounced 'frontal syndrome,'

with well-marked 'witzelzucht,' as well as a general loss of the ordinary inhibitions. His wound traversed both frontal lobes, as shown in *Fig.* 35.

Case 54.—Pte. A. B.—Admitted gen. hosp., Aug. 24, 1918; wounded three days previously.

On Admission.—Patient drowsy, semi-conscious, and entirely irrational; remembers nothing about injury, and his replies cannot be relied upon. Talks nonsense; is irritable, and tends at times to jocularity. Through-and-through wound, from right to left side of forehead. Brain extruding from exit wound.

Operation.—Novocain. Tripod incisions with excision of wound of exit. Large elevated fragment of bone extracted; extensive linear fracture lines running in all directions. Depressed and loose fragments picked out. Considerable extrusion of brain matter from dural perforation. Large masses of clot and disorganized brain sucked out of track. Hernia partially reduced. Partial closure, leaving open place over hernia. Entrance wound not touched.

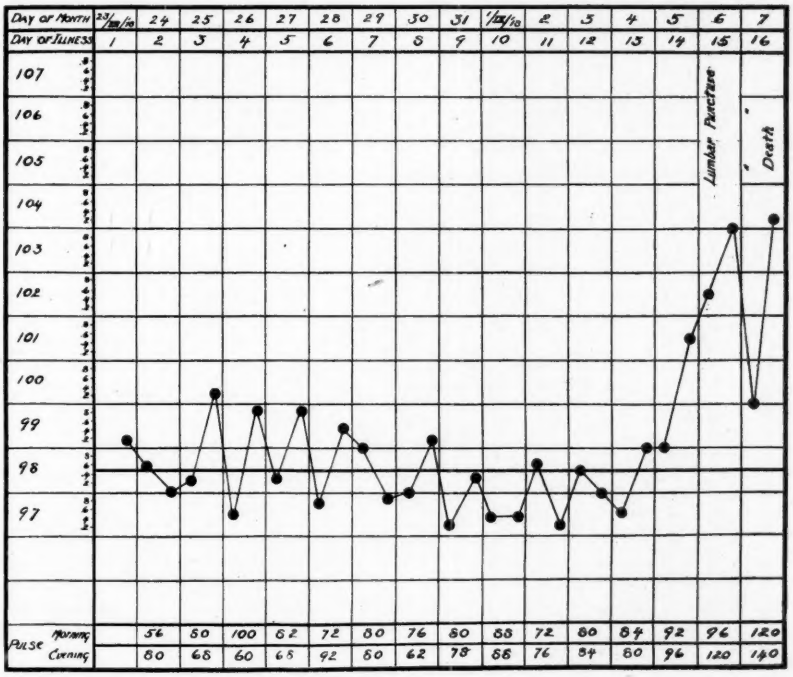


FIG. 34.—*Case* 54. Temperature chart.

Aug. 26.—Temperature normal. No further bulging of hernia. Patient slightly more rational. Sept. 1.—Patient in good general condition. Temperature normal. Hernia very slightly elevated above scalp level. Cultures from wound have shown *B. Welchii*, streptococcus, and staphylococcus. Sept. 6.—Sudden elevation of temperature to 102·5° this morning, and patient became unconscious within a few hours (*Fig.* 34). Up to this time temperature had been entirely normal. The hernia has remained clean and granulating, and has bulged only slightly above scalp edge. By lumbar puncture 45 c.c. of cloudy fluid under greatly increased tension were withdrawn. Sept. 7.—Culture from lumbar puncture fluid shows pneumococcus. Puncture was repeated to-day, and 20 c.c. of cloudy fluid withdrawn.

Patient failed rapidly, and died at 10 p.m.

Autopsy.—Moderate destruction of left frontal lobe at site of exit of missile (*Fig.* 35). Purulent basilar meningitis. Ventricles clear.

The second case illustrates a polyventriculitis which must have been fairly chronic, owing to the great thickness of the purulent exudate. That this patient lingered as long as he did was probably due to the fact that he developed a cerebrospinal fluid leak from his hernia, thus supplying drainage to the ventricle.

Case 55.—Pte. J. C. S.—Admitted field ambulance Sept. 2, 1918: "Shell wound head." Casualty clearing station, same date: "Dressing not removed; unconscious." Gen. hosp., Sept. 4.

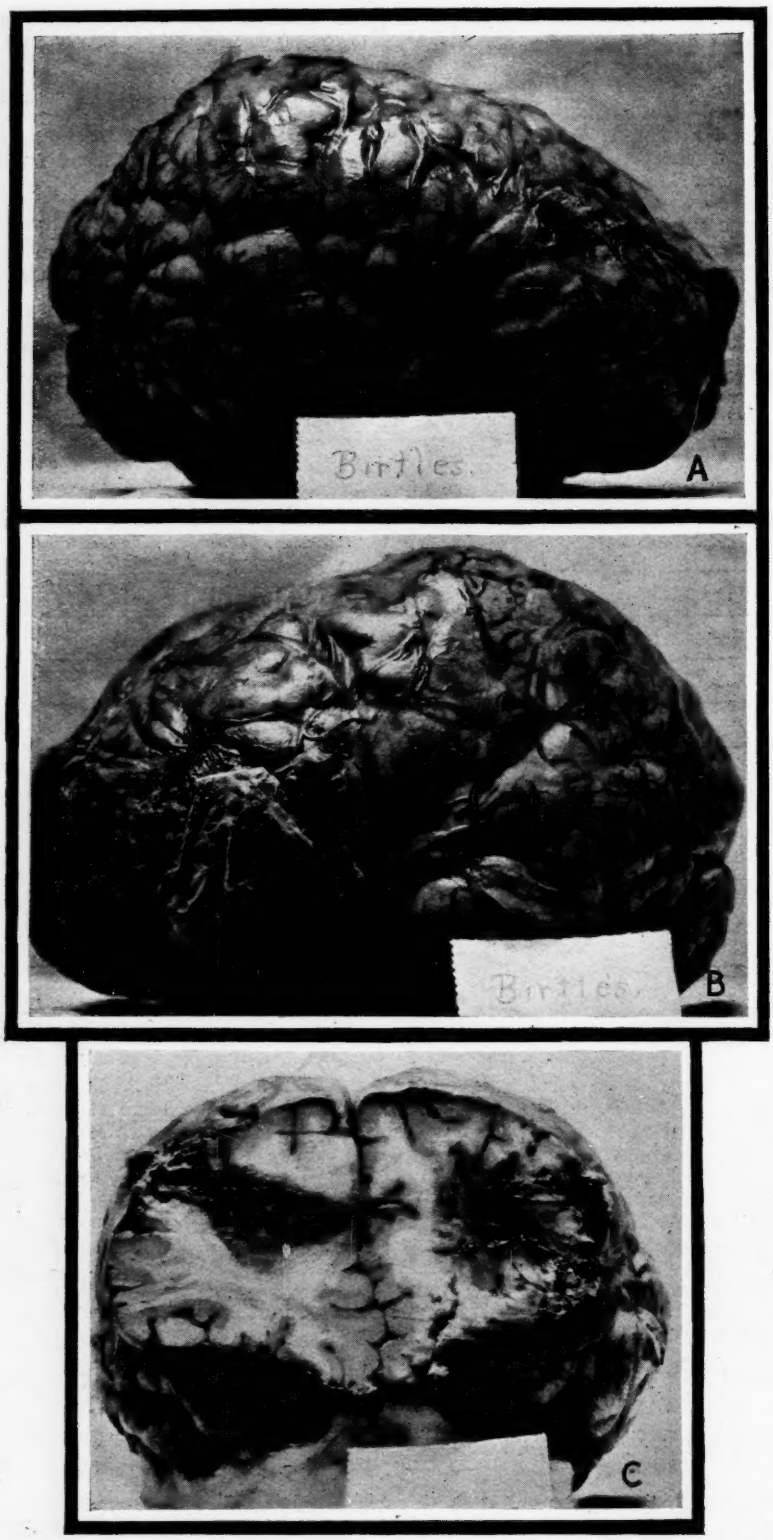


FIG. 35.—*Case* 54. (A) Surface of right hemisphere showing entrance wound in superior frontal convolution. (B) Surface of left hemisphere showing site of exit wound through inferior frontal region. (C) Section through both wounds to show track of missile.

On Admission.—Patient semi-conscious ; entirely disoriented ; can barely be made to respond. Left hemiplegia. Knee-jerks exaggerated on left, with ankle-clonus ; very marked jaw-clonus. Through-and-through wound from right post-auricular region to mid-line of vertex 4 inches above glabella ; large amounts of brain extruding. *X*-ray shows small clean hole at entrance wound and large comminuted fracture at exit.

Operation.—Sept. 5. Ether. Excision of wound of exit, with careful débridement of dirty subcutaneous tissue. Large hernia disclosed, with many elevated and depressed bone fragments and fracture lines running radially in all directions. Area of comminution removed. Rather sharp bleeding from two punctures of longitudinal sinus, controlled by the use of muscle. Catheter introduced into track for distance of 5 inches, and much disorganized brain and clot sucked out ; hernia greatly reduced. Partial closure. Entrance wound not touched.

FIG. 36.—*Case* 55. Lateral view of patient 25 days after operation, showing entrance wound just above right ear, and granulating hernia at exit.

Sept. 7.—Hernia bulging slightly above scalp edge, but seems quite clean. Cultures from wound show an anaerobic diplococcus and Welch-like organisms. Anti-gas-gangrene serum applied to hernia. Sept. 12.—Patient doing well. Hernia about size of English walnut. Entrance wound clean and healed. Beginning to move left leg, but there is still ankle-clonus and positive Babinski. Sept. 19.—Hernia about the same. Left leg can be moved freely now, but no movement of arm as yet. Cultures continually show anaerobic diplococci and diphtheroid bacilli resembling Welch.

Oct. 1.—Patient seems quite normal mentally. Hernia granulating, but still has moderate amount of very thin purulent discharge (*Figs.* 37 and 38). Oct. 7.—During the past few days patient's temperature has gone up to between 103° and 104°, and he has been vomiting. There is a well-marked cerebrospinal fluid leak from the hernia. Oct. 17.—Temperature showing large fluctuations from subnormal to 103°, and patient becoming drowsy and unable to take anything but liquids by mouth. Track leading from hernia investigated again, but no abscess could be found. Recently cultures from hernia have shown both a short-chain streptococcus and an anaerobic staphylococcus. Patient died this evening, with marked Cheyne-Stokes respiration and retraction of head.

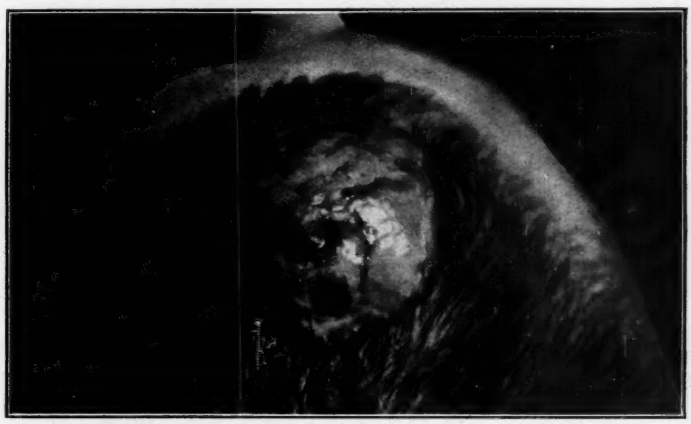


FIG. 37.—*Case* 55. Top of head showing position of exit wound, and hernia.

Autopsy.—The hernia connected with the anterior end of the right lateral ventricle, which was filled with thin purulent material. Left ventricle full of thick pus, and this pus extended down through third and fourth ventricles to the central canal of the cord. Around the base, completely

encircling the pons, medulla, and cervical cords, there was a purulent exudate ⅛ inch thick. Both choroid plexuses were surrounded by a similar exudate. The surface of both cerebral hemispheres, and the hemispheres themselves, other than the parts above described, seemed perfectly normal, except for a slight softening around the area of the hernia in the right frontal lobe. Wound of entrance was demonstrated to be perfectly healed, as was also the track leading from this wound up as far as the ventricle.

In the next case the missile had traversed both ventricles, as shown in the photograph. This patient did very well during the first twenty-four hours after operation, but died on the third day with the clinical symptoms of pneumonia. This diagnosis was confirmed at autopsy.

Case 56.—Pte. F. C. H. Admitted gen. hosp., Aug. 31, 1918. Wounded two days previously.
On Admission.—Patient semi-conscious; responds vaguely, but makes some attempt to protrude tongue, etc., when asked to do so. Pupils equal; pulse full. Complete motor

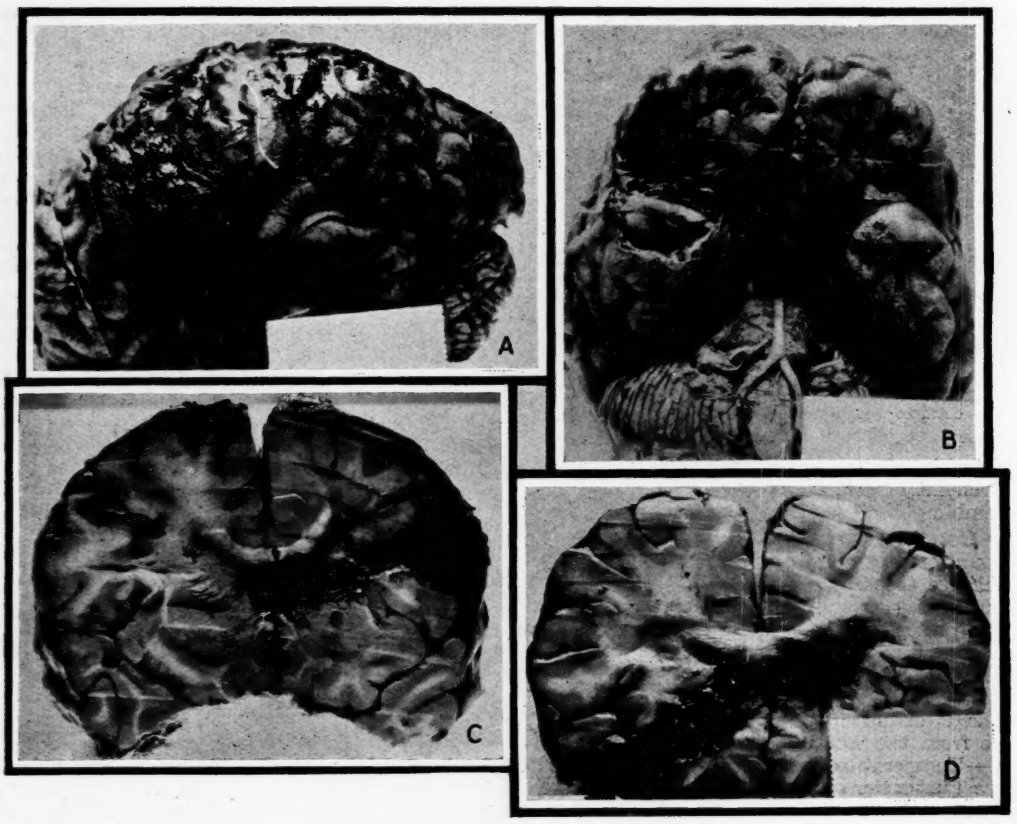


FIG. 38.—*Case* 56. (A) Surface of left hemisphere showing entrance wound in mid-frontal region. (B) Inferior surface of brain, showing exit wound through inferior frontal region and tip of right temporal lobe. (C) Showing track from entrance wound into left lateral ventricle. (D) Continuation of track through right lateral ventricle to exit.

aphasia; right facial palsy; right arm and leg can be moved, but weaker than left. Through-and-through wound, from left temporoparietal region to right temple; brain extruding.
Operation.—Novocain. Exit wound excised. Area of comminution encircled and removed; radiating fracture lines extending forward and posteriorly. Catheter passed into track, which goes through both lateral ventricles, and much pulped brain and clots sucked out. Bloody contents of ventricles evacuated. Partial closure.
Sept. 2.—Patient did quite well for first twenty-four hours after operation, but last night became drowsy, with respirations increasing in rate, and marked cyanosis. Marked clinical signs of consolidation of right lung and of bronchitis on the left. Died at 9 a.m.
Autopsy.—Brain showed moderate hæmorrhage and contusion around track of missile, which led through both ventricles (*Fig.* 38). Moderate hæmorrhage and slight cortical destruction

at base around wound of right temporal region. No meningitis. Upper and lower lobes of right lung entirely consolidated; left lung normal.

The other five cases were all of the hopeless variety. Their records follow.

Case 57.—Pte. A. H. Admitted gen. hosp., Oct. 3, 1918. Wounded two days previously.

On Admission.—Semi-conscious; can barely be made to respond. Deep reflexes increased on left, with questionable Babinski and clonus. Partial left hemiplegia. Through-and-through wound, with entrance at mid-line of forehead and exit through right ear. *X*-ray shows fractures at entrance and exit. No foreign body intracranially.

Operation.—Ether. Right decompression by vertical incision over usual temporal site. Very extensive comminution of squamous bone, with radiations to the vault and base. Loose fragments picked out. Considerable extrusion of disorganized brain through lacerated dura. Many small bone fragments removed from brain, and considerable amounts of clot washed out; hernia not entirely reduced. Closed in layers with rubber-tissue drain.

Oct. 4.—Patient showed no improvement after operation, and died, with rising pulse and respiration, at 11 a.m.

No autopsy, in view of the fact that at operation it was apparent that death was due to cerebral laceration and shock.

Case 58.—Pte. C. M. Admitted gen. hosp., April 18, 1918. Wounded thirty-six hours before.

On Admission.—Patient unconscious, with stertorous breathing. Evident left hemiplegia, with increased reflexes. Through-and-through wound, from left frontal to right parietal; brain extruding at both entrance and exit.

Operation.—Novocain. Exit wound excised, and bursting fracture disclosed around perforation of skull. Many bone fragments and débris removed. Small area cleared away around the torn dura; track cleaned with catheter for short distance. Entrance wound also excised and a few small bone fragments removed. Both wounds closed with rubber-tissue drainage.

April 19.—Patient never recovered consciousness; died at 8.40 p.m.

Autopsy showed frontal lobe at site of injury almost completely destroyed. Considerable laceration of other frontal lobe also. Much extradural and subdural hæmorrhage.

Case 59.—Pte. G. T. Admitted gen. hosp., Oct. 16, 1918. Wounded two days previously.

On Admission.—Semi-conscious. Both eyelids tremendously swollen, and closed with œdema and ecchymosis. Through-and-through wound, from mid-line of forehead, the exit being in the left cheek just below zygoma. Brain extruding from both wounds.

Operation.—Ether. Wound of entrance excised; comminuted fragments of skull removed, disclosing fracture lines radiating in all directions. Catheter introduced into track to depth of 4 inches. A good deal of clot and disorganized brain evacuated. Partial closure. Exit wound investigated and found to run upwards to base of skull. The maxilla, zygoma, and lateral wall of orbit were all comminuted. Cigarette drain introduced.

Patient showed no improvement following operation, and died at 7 p.m. Cultures from wound showed *B. Welchii* and other anaerobes.

Case 60.—Pte. A. F. T. Admitted gen. hosp., Aug. 10, 1918.

On Admission.—Patient in very bad condition; face pale, pulse weak and thready. Semi-conscious. Partial motor aphasia and complete right hemiplegia. Through-and-through wound, from left frontal to left parietal region; quantities of foul-smelling brain extruding from both wounds. *X*-ray impossible to obtain owing to patient's restless condition.

Operation.—Ether. Temporoparietal flap turned down, with excision of both wounds. Masses of disorganized brain washed out; many large and small, loose, and indriven bone fragments removed. Wide excision of bone around fracture defect. Large amounts of subdural clot washed out; tension greatly reduced. Wound left wide open; covered with rubber tissue.

Aug. 11.—Patient gradually declined after operation; died at 9 a.m. Cultures from wound showed *B. Welchii* and streptococcus.

Autopsy.—Extensive encephalitis of left hemisphere, with destruction of a large part of this half of the brain.

Case 61.—Cpl. A. W. Admitted gen. hosp., April 12, 1918. Wounded twenty-six hours previously.

On Admission.—Unconscious and tossing about. Through-and-through wound, from left frontal to left occipital; brain extruding. *X*-ray shows perforating wound of skull with stellate fractures at entrance and exit.

Operation.—April 13. Novocain. Exit wound excised, disclosing bursting fracture with many large elevated loose pieces. Much spontaneous extrusion of clot and disorganized cerebral tissue. More clot and pulped brain removed by suction. Partial closure. Anterior wound not touched.

April 15.—Patient never regained consciousness. Death at 11.50 a.m.

Autopsy.—Extensive extradural clot. Purulent exudate over considerable area around exit wound. Left temporal lobe almost completely destroyed. Track of missile traversed left lateral ventricle.

Group IX.—BURSTING FRACTURES.

There were no examples of this type of injury in the operated series. The one case of this sort was treated successfully with lumbar puncture, and is referred to below.

THE UNOPERATED CASES.

This term is used as applying simply to the relatively small number of patients who were evacuated from the advanced medical stations without operation and were not operated upon at the base for various reasons. They are referred to for the sake of completeness in giving the details of any series. There were 39 such cases, and they are best discussed under two heads :—

1. THOSE WHICH LIVED.—This group comprises 26 cases, divided as follows : *Group II*, 14 ; *Group IV*, 2 ; *Group V*, 8 ; *Group VIII*, 1 ; and *Group IX*, 1.

The *Group II* cases were not operated upon usually because their wounds were small and healing well by the time they arrived, or because their wounds were very large and closure would have been impossible. In *Groups IV* to *VIII* the patients had often arrived two to four days after injury, and were doing so well that it was not deemed advisable to run the chance of opening up their cerebrospinal-fluid spaces by operation and thus subject them to the probability of a meningitis. The large number of *Group V* cases in this unoperated series shows how well metallic foreign bodies may be tolerated in the brain. A subsequent report from the home hospital in England of the case having the largest retained fragment, showed that the patient was in perfect condition three months after he left this base. The *Group IX* case had a minute wound on the vertex, and a typical extensive bursting fracture. This patient's clinical record is appended.

Case 62.—Pte. J. F. Admitted field ambulance, Aug. 28, 1918 : "Shell wound, head, and hand, left." Gen. hosp. same date.

On Admission.—Patient drowsy and semi-conscious ; responds vaguely. Bilateral moderate exophthalmos ; subconjunctival hæmorrhages, both eyes. Fundi show congested discs, with hæmorrhages in blotchy areas over both retinæ. Reflexes normal. A very small, apparently penetrating wound at mid-line of vertex. *X*-ray shows extensive bursting fracture of vault, with extensions to the base along frontal region.

Lumbar Puncture.—Fifteen c.c. of slightly blood-stained fluid obtained, not under increased pressure.

Aug. 30.—Cultures from lumbar-puncture fluid show no growth. Patient somewhat less drowsy this morning. Sept. 6.—Patient's general condition has improved every day, and he now seems quite rational and normal mentally. Sitting up in bed ; feeds himself, etc. Evacuated to England.

Subsequent Report.—London, Nov. 11, 1918.—Wound healed. No motor or sensory disturbance. No aphasia. Dimness of vision in right eye. Mental state good. Discharged, unfit for further service.

2. THOSE WHICH DIED.—These were 13 in number. Operation was withheld for one of two reasons, namely, the patients either died before operative measures could be instituted, or the destruction of cerebral tissue was evidently so great that operation offered no advantage. Six of the cases showed a culture of gas bacillus from their wounds ; others were undoubtedly suffering from such an infection, but no cultures were taken, because they died within a few minutes or hours of admission. The fatalities were divided among the types as follows : *Group IV*, 2 ; *Group V*, 5 ; *Group VI*, 4 ; *Group VII*, 1 ; *Group VIII*, 1.

THE OPERATIVE MEASURES.

In general, as mentioned previously, the method of operating on the penetrating cases was along the lines proposed by Colonel Cushing in his article in the *British Medical Journal*, Feb. 23, 1918. Three or more holes were made around the fractured area, and these holes connected by means of a cutting forceps such as the Montenovesi. The block of bone thus obtained was then lifted off, often intact, but sometimes in sections, owing to the fact that fracture lines usually run off from the penetrated area, thus dividing the block. The superficial detached bone fragments were then picked out.

The next step was usually to take a Carrel syringe and gently squirt normal saline

into the more superficial part of the track through the dural penetration. This at once washed out certain small pieces of bone, and also much soft disorganized brain tissue. A small, soft, round-nosed catheter was then introduced into the track, and further pieces of indriven bone easily palpated and extracted with forceps, while at the same time the deep-lying pulped tissue was sucked up into the catheter, and when the latter was withdrawn, its contents were expelled by the bulb on the end of the syringe.

In this way, after a little experience, the track of bone fragments or a missile may be followed into the brain without the slightest chance of the catheter going off into the more resistant normal tissue on either side. If the ventricles have been penetrated, their bloody contents can be evacuated by means of this suction with the catheter, as was done in many of the cases reported here. It has often been possible to clean out a track to the depth of five or six inches.

If a metallic foreign body be present, it can also of course be palpated with the catheter, and in fact one can tell quite frequently whether the catheter is touching metal or bone merely by the difference in sensation which is transmitted along the catheter to the finger. When the foreign body is thus located, its extraction by means of a magnet, or by delicate forceps where the missile is lead, can usually be accomplished.

It was our custom, when a foreign body lay at a considerable depth within the dura, say roughly beyond 4 inches, simply to clean the track as thoroughly and as far in as possible, and not make any prolonged effort to obtain the metal. The results of such relatively conservative treatment have usually been quite satisfactory.

The only other point of operative interest was referred to earlier in this report, namely the leaving of the wounds wide open over the area of dural penetration. We think that this is of prime importance in base cases, or in cases that are operated upon after an interval of over eighteen hours from the time of their injury. When primary closure of penetrating cranial wounds is attempted at the base, even if reopened after twenty-four hours, the infection has almost always had just the added impetus which it needs, and the chances of recovery are thereby greatly lessened. The advantages of this open method were most striking in *Group IV*, in which all cases operated upon in this way recovered, whereas less than half of those survived which were closed and then reopened.

In regard to anæsthesia, we have used the novocain and adrenalin as advocated by Colonel Gray, De Martel, and others, in 90 per cent of the cases, and it has given very great satisfaction. In about 10 per cent of cases, i.e., those which have been unruly, with inhibitions lost, or where the enucleation of an eye was necessary, a general anæsthetic of ether was used.

As to the surgical after-treatment of the penetrating cases, there are two considerations worthy of mention. Inasmuch as the gas bacillus was the infecting organism in such a large number of the cases, it was deemed wise, in addition to the usual operative measures, to make free use of the anti-gas serum. Many cases were given continued doses of this subcutaneously and intravenously, but no effect was noticeable clinically. On the other hand, several cases were treated by applying the serum directly to the wound in the brain or by soaking pledgets of cotton with the serum and placing these around and in direct contact with the hernia cerebri. In these patients a very rapid diminution in the number of organisms in the wound was demonstrated bacteriologically. Some of the patients thus treated made quite surprising recoveries, while in others life was prolonged many more days than would ordinarily have been expected judging from the grade of infection and the experience of other cases.

The other notable measure in the after-treatment was the dressing of brain fungi. These are, we believe, a very necessary evil in dealing with late cases, and if the attempt is made to close them over with skin flaps it is a step which is entirely unsurgical, because it is simply holding in the infection. Likewise the use of pressure dressings over cerebral herniæ defeats the purpose, as the brain is trying to get rid of the extra pressure due to infection, and should be given help, rather than hindrance by counter-pressure against it. The method which we found in every way the most satisfactory was to cover the fungus with thin gutta-percha tissue, thus letting the secretions slide out easily on all sides, and

at the same time preventing any damage to the surface of the hernia by contact with dry gauze. Outside the gutta-percha and around the hernia is then placed a ring of cotton-wool, which forms a wall against pressure from the dressing which is placed over the whole.

GENERAL COMMENT ON THE SERIES.

One of the most striking features of the series is the large percentage of cases having a gas infection. This simply illustrates once more the necessity of early operation on patients with cranial injuries of war. There are certain cases which would do well either after early or late operation, i.e., those with relatively slight cranio-cerebral destruction, in whom infection is being taken off largely by the brain tissue. There is another type—those with large open wounds, either of gutter type or penetration with large missiles—which, if not immediately killed, frequently live on from two to seven days if not operated upon. These are the cases most benefited by early operation, as, by the time they get to the base, infection has received such a start that operative measures but rarely forestall a fatality.

It will be noticed also that there were very few examples of cerebellar wounds in the series. This is another type of case in which early operation is most important, as every hour they wait, and every jolt they receive in transportation, increases their chance of sudden death because of the proximity of the wound to the respiratory centre.

Some of the subsequent reports given with the case records have come as letters from the patients themselves ; but by far the larger number are from the post cards furnished by the Medical Research Committee, to whom special acknowledgement is due. In conclusion, I wish to express my very great thanks and appreciation to Colonel Harvey Cushing, Director of U.S.A. Base Hospital No. 5, to Colonel Andrew Fullerton, Surgical Consultant of this base area, to Lieut.-Colonel Gordon Holmes for many helpful consultations, and to Major John J. Morton for much valuable assistance and co-operation. Many thanks are due also to Sergeant Fuwa and Private Elliott, whose work in the *x*-ray and photographic departments has contributed largely to the illustrative features, while many members of the department of pathology have given much willing aid.

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SPECIMENS OF GUNSHOT INJURIES OF THE FACE AND SPINE,

CONTAINED IN THE ARMY MEDICAL COLLECTION NOW ON EXHIBITION IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND.

By Professor ARTHUR KEITH, F.R.S., Conservator of the Museum, and Captain MORTON E. HALL, C.A.M.C.

This article is a continuation of the series commenced in the April number of this journal. In these articles a description is given of the more typical specimens contained in the War Office Collection of pathological specimens. The Collection has been prepared and placed on exhibition in the Museum of the Royal College of Surgeons of England. Its final destination has not yet been settled.

In the last number of this journal we gave an account of the more typical gunshot injuries of the cranial part of the skull as illustrated by macerated specimens. In the present paper we propose to describe briefly some of the more typical lesions of the facial part of the skull, and also certain specimens which illustrate the injuries of the spine. We have confined our attention to the macerated specimens only; but visitors to the Collection will do well to study the facial injuries which Prof. S. G. Shattock and Mr. Cecil Beadles have mounted in the 'wet' series, and also examine the excellent war models prepared under the care of Major A. C. Valadier, C.M.G., to illustrate gunshot injuries of the face and the results obtained in their treatment by plastic operations. There are also very complete series of casts and photographs showing the methods adopted by Captain Derwent Wood, A.R.A., at the Third London General Hospital, to mask deformities which follow facial injuries.

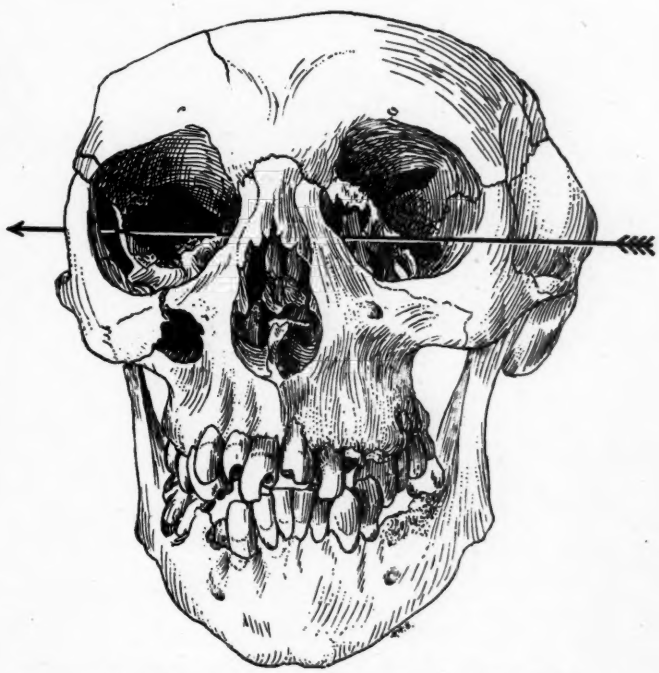


Fig. 39.—No. 2.201. Anterior view of cranium, showing injury to both orbits. The arrow shows direction of missile.

GUNSHOT INJURIES OF THE FACE.

Gunshot injuries of the face have offered a special opportunity to the surgeon to carry out reparative operative procedures, and the improvement which has been made in plastic surgery during the War has been remarkable. Several workers have made special study of the underlying injuries to the bone, and the War Office Collection has been enriched by many specimens collected by these workers. There are 37 specimens showing gunshot injuries of the facial bones. The

specimens have been roughly classified according to the particular area of the face injured, i.e.: (1) *Orbit*; (2) *Maxilla*; (3) *Mandible*.

1. INJURIES TO THE ORBIT.

Twenty-one specimens in the collection show injury to the orbit, and of these, three show damage to both orbits.

Specimen No. 2.201 (*Fig.* 39) is that of a transorbital gunshot wound with destruction of the floor of the right middle cranial fossa. The soldier was wounded on July 1, 1917, and admitted to No. 4 General Hospital in an unconscious condition, with apparently

FIG. 40.—Drawing of patient before death, showing facial appearance and extent of superficial injury.

a fracture of the base of the skull. *Fig.* 40 is from a drawing of this patient by Mr. Maxwell, R.A.M.C., showing his condition when admitted to No. 4 General Hospital. There was a pulsating exophthalmos of the right side, which, later, began to discharge externally. Death took place three days after injury, from meningitis. At autopsy, the inferior surface of the right temporal lobe was found to be destroyed and covered with an extra-

and intra-dural hæmorrhage. The missile entered the left eyeball, perforated the interorbital septum, and made an exit in the right temporosphenoidal region. There is marked destruction of the interorbital septum, ethmoidal and sphenoidal sinuses, and the floor of the right orbit. There are multiple secondary fractures in the floor of the anterior cranial fossa, cribriform plate, right middle cranial fossa (of which the anterior portion is absent), and of the calvaria in both the frontal and occipital regions. The right malar bone shows fracture of both its zygomatic and frontal processes, being entirely loose from its attachments, except that of the right maxilla. The latter bone shows loss of its orbital surface and a complete fracture through the body. This specimen is of interest as showing an indirect fracture of the right maxilla and processes of the right malar bone, and it is suggested that the soft tissues of the orbit may have aided in producing this result. The fracture of the basis cranii was apparently due to direct impinging of the missile against the floor of the right middle fossa. The vertex of the skull was also fissured by indirect force, in its frontal as well as its occipital region.

Specimen No. 1.7125 (*Fig.* 41) is that of a temporo-orbital wound of the skull, evidently caused by a bullet which entered 1 inch above and in front of the right auditory meatus and made its exit through the left orbit. The aperture of entrance, irregularly triangular (15 by 15 mm.), seems to be so shaped from the oblique tangent of impact. It will be seen that the missile left the cranial cavity by the right sphenoidal fissure, ploughed across the interorbital septum (ethmoid), and came out on the nasal side of the left eye. The patient was admitted to No. 3 General Hospital, on Sept. 5, 1918, and died Sept. 7. He was blind, the left eye being disorganized, and he had symptoms indicating a cerebral irritation. The under surface of the right temporal lobe was found to be lacerated, and there was an extensive subdural hæmorrhage.

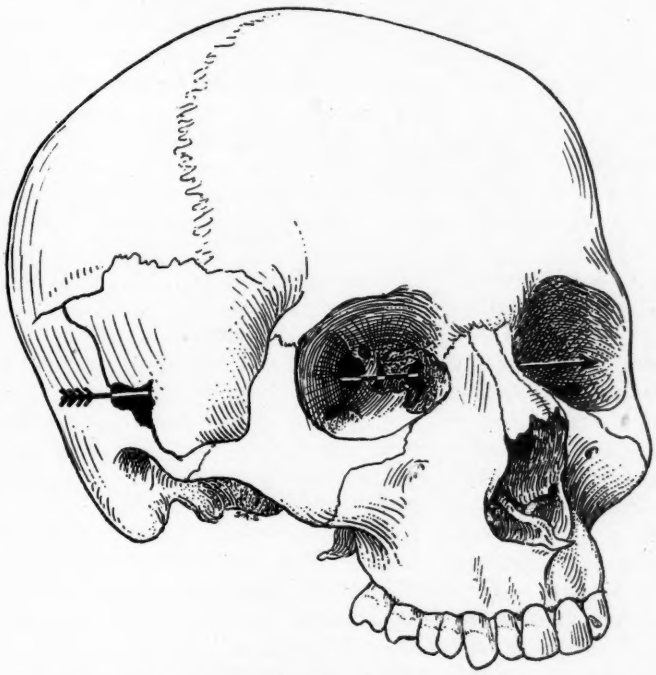


FIG. 41.—No. 1.7125. Right anterolateral view of cranium, showing perforating gunshot wound involving both orbits. The arrow indicates direction taken by missile.

From the aperture of entrance two short fissures run, one to the base of the zygoma and the second upwards to the lamboid suture, which is separated for 3 cms. in length, forming a 'T' with the main fissure. The interesting feature of this specimen is the slight injury to the bony walls of the orbits compared with the extensive injury seen in specimen No. 2.201 (*Fig.* 39). The base of the cranium shows comparatively slight fissuring, and no indirect fracture of the facial bones has occurred. Incidentally we may mention that this specimen shows that the malar bones possess a texture quite different from that of the other bones of the face. The skull had been cleaned in calcium chloride solution, which has changed the texture of all bones save the malars.

Specimen No. 2.202 (*Fig.* 42) shows an extreme injury to both orbits and the bones of the face. The missile entered the outer wall of the right orbit at the fronto-malar

junction, and, passing through both orbits and interorbital septum, made its exit on the left cheek over the prominence of the left malar bone, which has been markedly comminuted and carried away. Extreme comminution of all the facial bones, and of the floors of the anterior and middle fossæ of the basis cranii, has taken place. The two palatine bones show transverse fracture, and it has so resulted that the palatal and alveolar portions of both maxillæ have been entirely separated from the remaining portion of the skull.

FIG. 42.—No. 2.202. Anterior view of skull, showing transorbital gunshot injury, with extensive comminution of walls of both orbits and bones of face. The palatal portion of the two maxillæ is separated from the superior portion of skull.

Fracture lines extend upwards from the anterior fossæ through the frontal bone, and, although the specimen is incomplete, it is apparent that the anterior portion of the frontal bone, including the supraciliary ridges and orbital margins, has been separated from the remaining portions of the cranium.

The patient was wounded on July 10, 1917, and, in spite of the extensive injury to the basis cranii, lived for thirteen days. There was destruction of both eyeballs. He died on July 23, of meningitis. The bones of the cranial cavity are thin, and those of the face are delicate, features which are contributory to the extent of the injury.

Specimen No. 2.207 (*Fig.* 43), consists of the anterior portion of a cranium which shows an extensive comminution of the right orbit by a shell fragment that lodged in the soft tissues at the superior medial angle of the orbit.

The soldier was wounded on June 30, 1917, and the right eye removed at a casualty clearing station a few hours afterwards. He was transferred to No. 4 General Hospital, where he died on July 8 from suppurative meningitis. The missile entered the right side of the face in front of the angle of the lower jaw, carrying away the right coronoid process. It passed upwards through the lateral wall of the right orbit, and struck the frontal bone at the superior medial angle of the orbit, perforating the frontal sinus and floor of the anterior cranial fossa. The latter shows marked comminution. The anterior tip of the right frontal lobe of the brain was lacerated, and portions of indriven bone were found embedded in it. The floor of the right orbit has been shattered, and a complete fracture of the body of the right maxilla has occurred, with loss of the anterior wall of the right antrum for an area of 12 by 5 mm.

FIG. 43.—No. 2.207. Anterolateral view of cranium, showing extensive comminution of right orbit. The missile (a fragment of shell) can be seen at the superior medial angle of right orbit.

In specimens Nos. 1.7125, 2.201, and 2.207, the missile in each case has entered one or both orbits. The War Office Collection

contains two specimens in which the injury has been caused by a glancing blow from a shell fragment, and in which the lateral wall of an orbit has been carried away.

Specimen No. 1.7135 is one of this type. There is a temporo-orbital wound of the left side of the face. The missile, a large shell fragment, evidently came from a posterior direction and, hitting a glancing blow, carried away a portion of the left temporal bone, the entire left zygomatic bone, left great wing of the sphenoid, and the superior wall of the left maxillary sinus.

The soldier, a German prisoner-of-war, was admitted to No. 3 General Hospital on Aug. 12, 1918, with a very septic wound. The left eye was severely lacerated, and was excised. He died suddenly on Aug. 15, from massive gas gangrene. No illustration is given of this specimen.

In the specimens described we have been rather more interested in direct injuries of the orbit; but one must also take into consideration a rather large group of specimens in which there has been an involvement of the orbit by a fracture or fissure radiating from, and continuous with, a primary injury to another area of the cranium. Unfortunately many specimens showing gunshot injuries of the calvarium are incomplete, the orbital portions not being preserved. In the Collection twelve specimens show this secondary involvement of one or both orbits. Of the twelve cases, nine present a direct injury of the frontal bone, two of the parietal, and one of the temporal. It would seem that secondary involvement of the orbit was much commoner in direct injury to the frontal, but also does occur from injury to other bones of the calvarium.

These secondary fractures and fissures radiating into the orbit have been described by some writers as indirect. Whether such a fracture produced disturbance of vision in any of the cases concerned could not be determined from the available histories. Where such a fissure involves the sphenoidal foramen and track of the optic nerve, one would reasonably expect symptoms of disordered vision.

One specimen in the collection (No. 1.77), is remarkable in presenting a severe injury to the left superciliary ridge down to the left orbital margin of the frontal bone, but in which there has been no involvement of the roof of the orbit. The injury was evidently a contused one, occurring in a thin frontal bone, no radiating fissures being produced.

The Collection has one specimen (No. 1.0221, *Fig.* 473, BRITISH JOURNAL OF SURGERY, vol. vi, p. 558) which is an example of pure indirect fracture of the left orbit. The chief wound, an aperture 52 by 20 mm., is situated on the temporal surface of the left parietal bone. From this aperture radiate into the skull five fissures—one extending through the ear to the base, another to the occiput, and a third to the left superciliary ridge. Besides this main series of fissures, there are secondary fissures in the roof of each orbit, on the floor of the right middle fossa of the skull, and in the right maxilla. The injury was due to a direct blow from a large shell fragment which did not lodge. The indirect fissures of both orbits and of the right maxilla were apparently due to 'explosive effects' of a peculiar kind. The right anterior sphenoidal fissure was involved in the indirect fissure of the right orbit.

Specimen No. 1.023 (*Fig.* 471*b*, BRITISH JOURNAL OF SURGERY, vol. vi, p. 557), is also an interesting specimen as showing a marked destruction of both orbits by the explosive effects of a rifle ball fired at close range. The bullet entered the mouth, passed through the base of the skull, and made an exit near the left parietal eminence.

2. GUNSHOT INJURIES OF THE MAXILLA.

The War Office Collection contains sixteen specimens showing a direct injury to the upper jaw. It must be noted that many of these cases show secondary injury to other bones of the face and cranium. Five of the specimens are perforating, through-and-through injuries in which the missile passed through both maxillæ.

Specimen No. 2.3455 (*Fig.* 44) is an example of a through-and-through wound, attended by an extensive destruction of the face. The missile, a bullet, entered the left cheek below the left inferior orbital margin and came out below the right malar eminence. The alveolar

portion of the upper jaw has been entirely separated from the orbits and nose, and the floor of the right orbit has been carried away. The medial wall of the right orbit, the vomer, and ethmoid bones have been comminuted. The soldier, a German prisoner, was admitted to No. 3 General Hospital on Sept. 3, 1918, with multiple septic wounds, and died on Sept. 8 of septic bronchopneumonia.

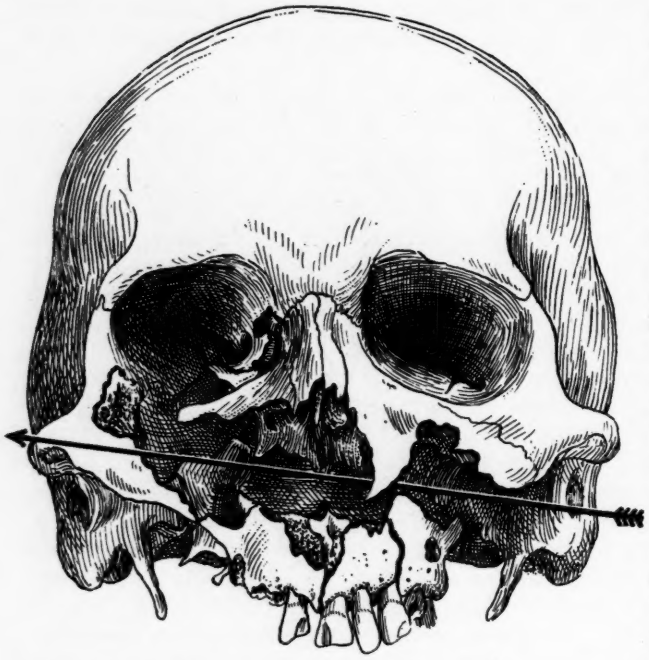


FIG. 44.—No. 2.3455. Anterior view of cranium, showing extensive destruction of face by a missile which perforated the upper jaw.

Specimen No. 2.441 (*Fig.* 45), is a good example of a direct injury to the left maxilla. A small missile, probably a fragment of shell, has perforated the anterior wall of the left maxillary sinus, passed along the inner wall of the left orbit, breaking the left mass of the ethmoid, and has entered the skull through the cribriform plate. There is comparatively little fissuring of the surrounding bones, the right orbit being intact. The soldier was wounded on June 11, 1917, and died the next day. The foreign body was not located, but the right frontal lobe was found to be lacerated, and contained a sinus along which the missile passed. An interesting feature in this case is the clean type of perforation of the maxilla, without fissuring.

Specimen No. 2.431 (*Fig.* 46) is one of multiple wounds of the face and head caused by fragments of shell. There are three main wounds, one, of the anterior alveolar portion of the upper jaw, a second, penetrating wound of the body of the right maxilla, and a third, a penetrating wound of the mastoid portion of the right temporal bone. A missile has apparently struck the incisor portion of the upper jaw, which has been carried away. The alveolar portion of the left maxilla, supporting the left canine and premolar with a portion of the body, covering the left maxillary sinus, has been separated from the surrounding bone. The dental splint used to retain the canine fragment *in situ* is still attached to the teeth. A second missile penetrated the body of the right maxilla, producing a clean-cut circular aperture 2 cm. in diameter, passed through the floor and medial wall of the right orbit, and lodged in the sphenoidal sinus just medial to the right optic foramen. The lateral wall of this orbit is not comminuted.

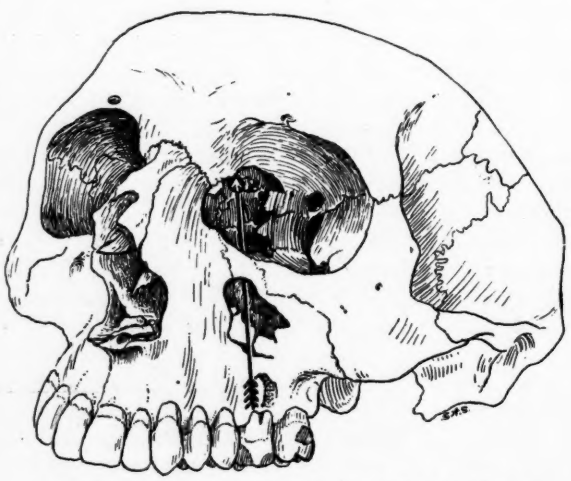


FIG. 45.—No. 2.441. Anterior view of face, showing uncomminuted perforating wound of left maxilla. The line of passage of missile through orbit is indicated by the arrow.

In specimen 2.431 (*Fig.* 46), as in No. 2.441 (*Fig.* 45), the body of the maxilla shows a clean aperture with no comminution. The soldier was wounded on May 31, 1917, and admitted to No. 20 General Hospital on June 5. He had a right facial paralysis and deafness. He developed meningitis and thrombosis of the right lateral sinus due to the mastoid wound, and died of toxæmia on June 26.

The Collection contains one specimen showing indirect fracture of the upper jaw, No. 1.0221, described under indirect fracture of the orbit. This specimen shows a linear fissure 4 cm. in length across the body of the right maxilla, as a result of the explosive effects of a contused injury and fracture of the left parietal bone.

In examining the histories of the cases which show injuries to the upper jaw, it is interesting to note that death occurred from secondary hæmorrhage in many of these cases, several days after injury.

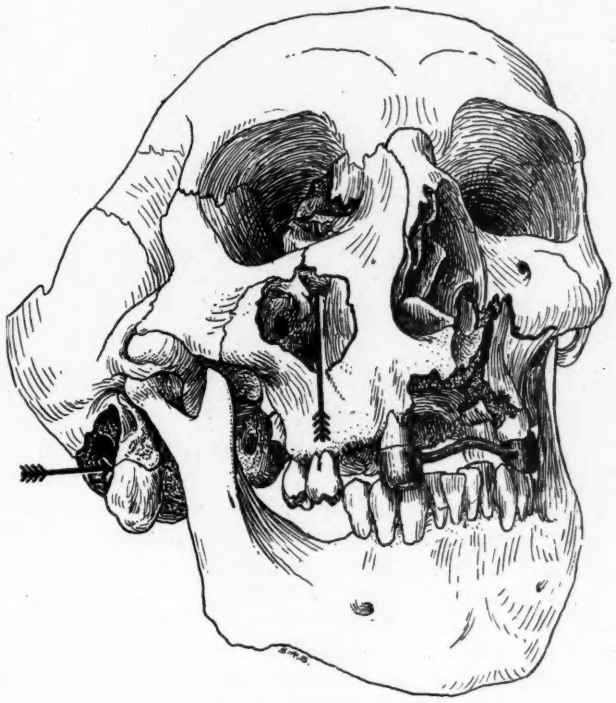


FIG. 46.—No. 2.431. Anterolateral view of cranium, showing multiple injuries. Note anterior dental splint applied to retain the canine fragment in position.

3. GUNSHOT INJURIES OF THE MANDIBLE.

The War Office Collection contains twenty-two specimens of gunshot injuries of the lower jaw. Considerable progress has been made during the war in methods for the splinting of fragments of the mandible and their treatment, and in several specimens in the Collection one sees the dental splint, applied during life, still in position.

We have divided fractures of the mandible into three groups according to the anatomical position of the injury, i.e.: (1) *Anterior*, those occurring along the line and in the neighbourhood of the symphysis; (2) *Lateral*, where the body of the mandible is chiefly involved; and (3) *Superior* group, where the ascending ramus and its processes are involved. This classification is essentially an anatomical one, but has an advantage clinically as well, when one considers the functions of the three main portions of the mandible. In each of the above groups the Collection presents specimens which represent various grades of injury, and we have recognized complete fracture of the mandible, partial fracture, and complete fracture in which there is considerable loss of bone. In the case of the ascending ramus, fracture of either the coronoid or articular process has been considered as a partial fracture. Three specimens show fracture of both bodies, caused by through-and-through wounds.

1. **Anterior Injuries to the Mandible.**—There are nine specimens showing injury with fracture in the neighbourhood of the symphysis.

In specimen No. 2.7701 (*Fig.* 47) there is a comminution of the symphyseal region of the mandible, caused by a fragment of high-explosive shell which struck the point of the chin. The soldier, age 28, was brought in dead on Nov. 23, 1917, to No. 3 General Hospital. He had died of hæmorrhage into the thorax caused by another wound. The missile has carried away a triangular area of the chin, and the inferior margin of the body,

on each side of the symphysis, has been shattered into several fragments. From the apex of the triangle, a gaping fissure extends through the body between the left lower canine and the left lateral incisor.

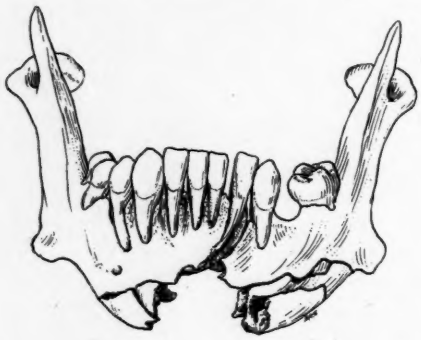


FIG. 47.—No. 2.7701. Anterior view of a mandible, showing comminution of the chin.

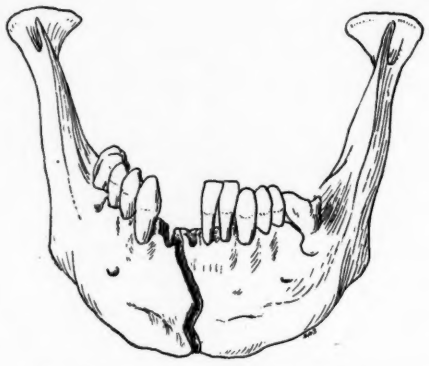


FIG. 48.—No. 2.784. Mandible, showing complete and probably indirect fracture in the region of the symphysis, without comminution.

Specimen No. 2.784 (*Fig.* 48) is an instructive one. There is a complete fracture through the body of the mandible extending from the socket of the right lateral incisor to the lower border of the symphysis. The two right lower incisors are missing, apparently from the injury. There is no comminution of the surrounding bone, and no abrasion of the surface of the bone can be seen; yet the history states that on admission to No. 3 General Hospital, April 30, 1917, there was a linear wound extending downwards through the lower lip for a distance of two inches. There was also a severe injury of the left orbit, and the patient died on May 4 of meningitis, by extension from the orbit through the cribriform plate. It is suggested that in this case the fracture was due to the lateral pressure of the soft tissues—the missile not striking the bone. One not unusually sees a similar type of fracture in the calvarium, and even in the long bones of the body.

In specimen No. 2.781 (*Fig.* 49) we have an example of comminuted fracture of the lower jaw in which there is considerable loss of the substance of the bone. The missile seems to have hit the surface of the mandible perpendicularly. The incisor region of the right side and the incisor and premolar region of the left side have been destroyed, representing a space, about 3 cm. in length, through the full thickness of the body. A fissure extends from the inferior end of the right lateral margin of the aperture, backwards through the right lateral body for a distance of 3 cm. The mandible is of a thin undeveloped form, from a soldier, age 25, who was wounded on April 28, 1917, in several places, and died on May 9 of septic bronchopneumonia.

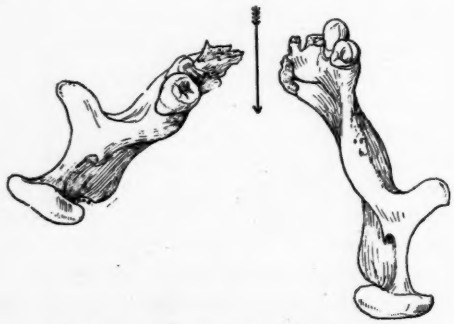


FIG. 49.—No. 2.781. Mandible, showing comminuted fracture in region of the symphysis, with considerable loss of continuity. The arrow indicates direction missile was travelling.

It is unfortunate that the War Office Collection does not contain a specimen showing partial fracture of the symphysis.

2. **Injuries to the Lateral Portion of the Mandible.**—There are ten specimens showing gunshot injury of the lateral portion of the mandibular body.

In specimen No. 2.7544 (*Fig.* 50) there is a marked comminution of the left molar-angular region of the mandible caused by a fragment of shell. The left ramus is entirely separated from the body, and the latter, for a distance of 4 cm., has been shattered into

four fragments. Fissures radiate from the site of perforation into the ramus. The missile passed entirely through the body, lacerating the dental nerve and artery, and escaped on the right side of the neck, injuring the sympathetic trunk and cervical spine. The soldier was wounded March 15, 1917, and died Aug. 23, from a secondary hæmorrhage.

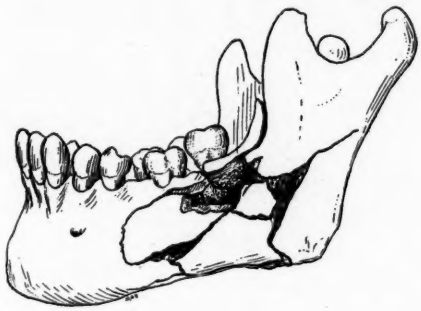


FIG. 50.—No. 2.7544. Left lateral view of mandible, showing extensive comminution of left molar-angular region caused by fragment of shell which perforated the body.

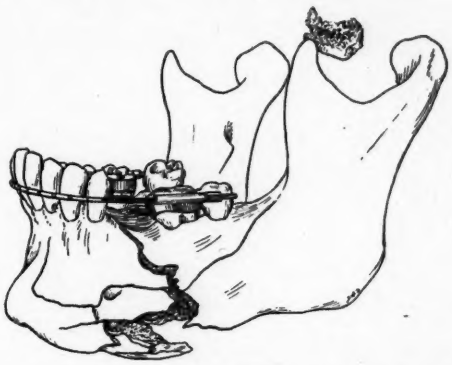


FIG. 51.—No. 2.755. Left lateral view of mandible, showing complete fracture in region of left premolar and first molar. Dental splint still *in situ*.

Specimen No. 2.755 (*Fig.* 51) presents a complete fracture of the body of the mandible in the region of the left premolar and first molar. The missile struck the bone near the lower border and passed towards the floor of the mouth. The inner or splenial table of the mandible is broken away and shattered; the inferior dental canal and vessels were ruptured and exposed. Fissures pass forwards and backwards from the site of fracture. The specimen is of special interest in that the dental splint made for this case has been left *in situ*. The soldier was wounded March 23, 1917; four days later he developed septic pneumonia (streptococcic), and died April 2.

In specimen No. 2.7554 (*Fig.* 52) we find a complete fracture of the right side of the body of the mandible, produced by the impact of a shell fragment (size 26 by 14 by 9 mm.). The missile struck the inferior margin of the body at the level of the right mental foramen,

FIG. 52.—No. 2.7554. Mandible, showing a complete fracture some distance posterior to point of impact of missile. The missile, a large fragment of shell (26 by 14 by 9 mm.), is shown below mandible.

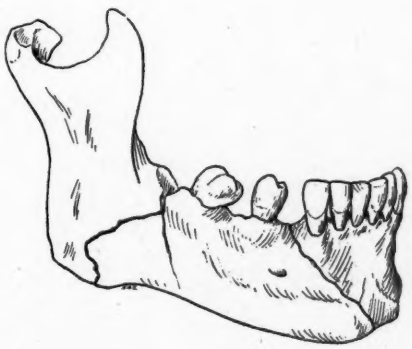


FIG. 53.—No. 2.801. Mandible, showing double fracture of right body.

shattering the margin for a distance of 4·5 cm. into several fragments, which have become detached. From the posterior end of the shattered area, a vertical complete fracture has been produced. This fracture line is 33 mm. from the point of impact of the missile.

The missile has been preserved. The soldier was wounded on Nov. 29, 1917, and died at a casualty clearing station one hour afterwards. It was found that the missile had glanced off the mandible and torn across the right carotid artery and jugular vein.

Specimen No. 2.801 (*Fig.* 53) illustrates a double fracture of the mandible caused by a blow with the butt end of a German rifle. The soldier was injured Oct. 26, 1917, and died in two days from generalized gas-bacillus infection. There are two complete fractures through the right body, one from the socket of the third right molar to just in front of the angle, and a second from the right anterior premolar to a point 6 mm. from the inferior end of the symphysis. From the posterior line of fracture, a fissure of the lateral plate of the body extends down to its inferior margin. The bone shows no indication of the point of impact of the weapon.

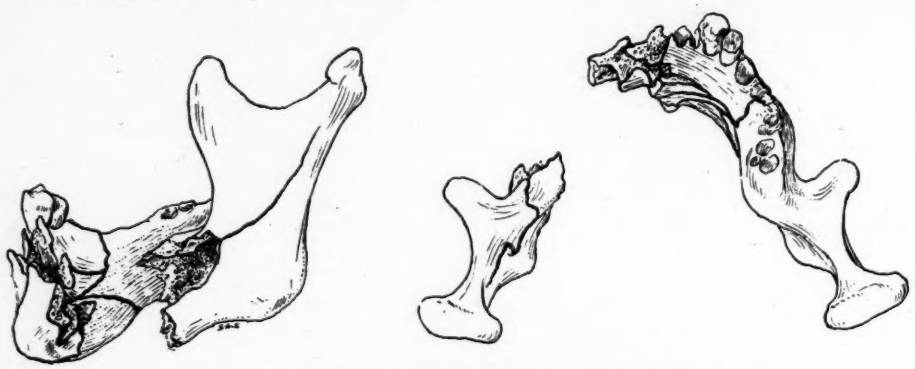


FIG. 54.—No. 2.758. Mandible, showing destruction of left half of body, with comminution of symphyseal region.

Specimen No. 2.758 (*Fig.* 54) shows an extreme comminution of a mandible, with considerable loss of bony tissue. The soldier was wounded Oct. 9, 1917, and on admission to hospital had a gunshot wound extending from the left angle of the mouth to the lower

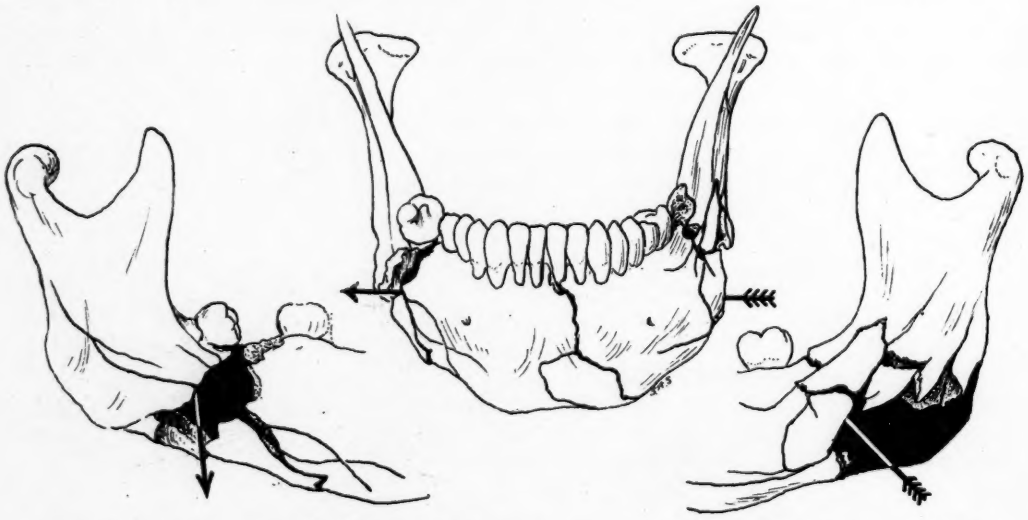


FIG. 55.—No. 2.754. Mandible, showing triple fracture produced by perforating bullet wound. The arrow indicates direction of the missile.

submaxillary region of the neck. Ten days after injury he developed a severe secondary hæmorrhage from the left facial artery. He died on Nov. 1 from bronchopneumonia. The wound of the face had begun to heal. The body of the mandible from the left premolar region to the base of the right coronoid process is markedly comminuted. Five

cms. of the left side of the body are missing. This case is remarkable in the extent of loss of continuity of the bone.

The War Office Collection contains three specimens of perforating gunshot wounds involving both sides of the body.

No. 2.754 (*Fig.* 55) is a good example of this type. The missile, a bullet, entered the mandible on the right side below the second molar and emerged on the left at a nearly corresponding point, perforating the base of the tongue in its passage. The right and left rami have been detached, and fissures ascend into them. There are three complete fractures, one at each of the points of entrance and exit, and a third at the symphysis, which has been produced by indirect violence. The soldier was wounded on April 14, 1917, and died two days later.

3. **Injuries to the Ascending Ramus and Processes.**—In specimen No. 2.721 (*Fig.* 56), the superior portion of the angle of the right mandibular ramus has been detached and broken by a bomb fragment. No fissures extend into the main portion of the ramus. A history of this case is not obtainable.

FIG. 56.—No. 2.721. Mandible in which a fragment of the angle has been detached. The arrow indicates direction taken by missile.

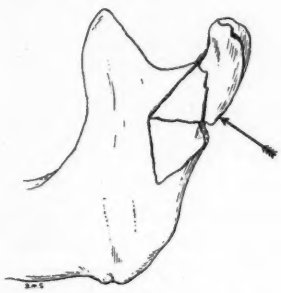


FIG. 57.—No. 2.739. Fracture of left condyle of mandible by shell fragment.

In specimen No. 2.739 (*Fig.* 57) there is a comminuted fracture of the left condyle of the mandible, by a fragment of shell which entered at the back of the neck, near the middle line. The soldier was wounded on June 28, 1917, and died on July 8 of secondary hæmorrhage. The left internal carotid and vertebral arteries were lacerated by the missile in its passage through the neck.

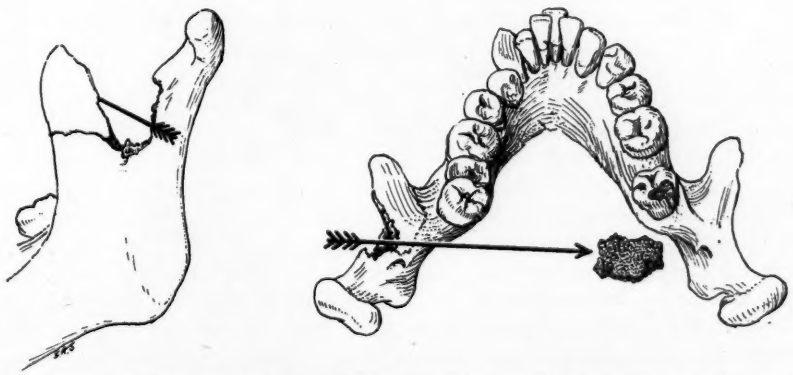


FIG. 58.—No. 2.705. Mandible, showing fracture of upper part of left mandibular ramus. The missile, a fragment of shell, is shown near the medial side of right ramus.

Specimen No. 2.705 (*Fig.* 58) shows a fracture of the upper part of the left mandibular ramus by a fragment of shell, which crossed the pharynx and then became lodged on the

deep aspect of the right ramus. The missile has perforated the left ramus at the lower margin of the sigmoid notch, carrying away a portion, and breaking the coronoid process at its base. The soldier, age 25, was admitted to hospital Oct. 16, 1917. The external carotid artery was tied on account of hæmorrhage, and there was also a left facial paralysis. A secondary hæmorrhage developed on Oct. 24, for which the left common carotid artery was tied. A right hemiplegia followed, with complete aphasia. Death occurred on the same day, the result of a further secondary hæmorrhage.

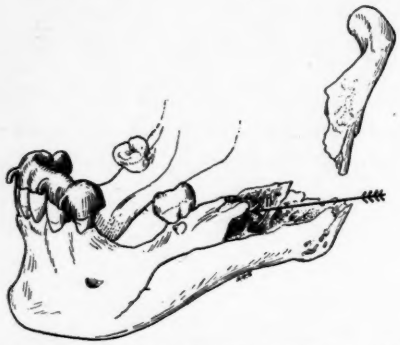


FIG. 59.—No. 2.751. Mandible, showing comminution of left ramus, only the condylar process and angle remaining. The dental splint attached to lower teeth was used to fix mandible to upper jaw.

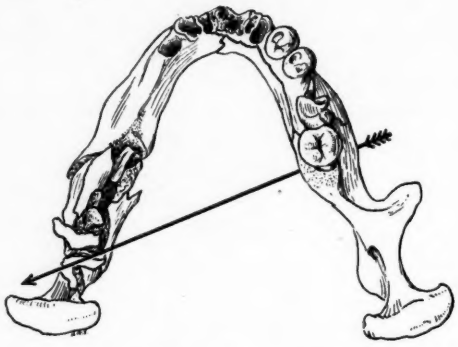


FIG. 60.—No. 2.748. Comminuted fracture of left mandibular ramus, with detachment of condyle. Direction taken by missile is shown by the arrow.

Three specimens in the collection show marked comminution and shattering of an ascending ramus. In No. 2.751 (*Fig.* 59) the left ramus has been largely carried away, only the condylar process and angle remaining. The latter is undergoing absorption. A fissure passes along the body of the jaw from the site of fracture to a point just posterior to the left mental foramen. The inferior dental canal is exposed. The right ascending ramus is seen to be fragile and very much under-developed. The soldier was wounded April 2, 1917, by a bullet which entered the left cheek and passed out at the angle of the right ramus. He died on April 29, of septicæmia.

FIG. 61.—No. 2.7845. Skull, showing extensive fracturing of the facial bones and ramus of the mandible by a shell fragment.

Specimen No. 2.748 (*Fig.* 60) presents a similar but more extensive comminution of the left ramus. The condyle is detached and the coronoid process largely carried away. There is also a complete fracture of the body at the level of the third left molar. The specimen is of special interest in showing comminution of the right body, with two complete fractures, due to indirect violence. The alveolar portion supporting the two premolars is loosened from its attachment. The soldier was wounded on April 12, 1918. The bullet entered the right side of the neck, perforated the tongue and floor of the mouth, and ultimately produced fracture of the left ramus.

Specimen No. 2.7845 (*Fig.* 61) is one in which there has been extensive fracturing of the face by a fragment of shell. The right malar bone and part of the right ascending ramus, including the condylar neck, have been carried away. There is a second fracture through the right body near the posterior molar region, and in this way a large segment of the ascending ramus and angle has been displaced from its normal position. The missile apparently struck the right malar eminence from in front. The extent of the lesion is probably due to the edentulous condition of the soldier and the thinness and delicacy of the facial bones.

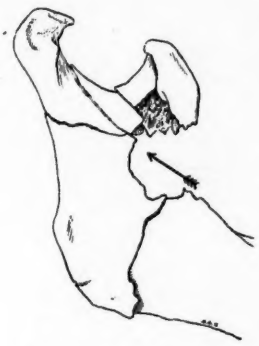


FIG. 62.—No. 2.754. Comminuted fracture of right ramus, caused by a missile which struck at base of coronoid process.

In specimen No. 2.754 (*Fig.* 62) the missile, a shell fragment, has perforated the right ascending ramus near the base of the coronoid process, carrying away a considerable portion of the latter. The angle and the condylar process have been detached, and the remainder of the ramus reduced to fragments. The soldier was wounded on May 14, 1917. On May 18 he developed a secondary hæmorrhage from the external carotid, which was tied; he died the following day.

GUNSHOT INJURIES OF THE SPINE.

The War Office Collection contains 50 specimens showing a wide variety of spinal injuries produced by various missiles. The collection has recently been enriched by 15 specimens forwarded from No. 3 General Hospital. A description of some of these has already been given by Colonel William Thorburn, C.B., and Major George Richardson (BRITISH JOURNAL OF SURGERY, vol. vi., p. 481). Visitors to the collection are advised to study the specimens in conjunction with the pathological findings in the spinal cord given in the above-mentioned article. In the 'wet' series several spinal cords have been cut transversely, and segments have been removed and mounted beside the cord, showing intraspinal hæmorrhage caused by indirect force where the injury has not directly involved the spinal canal. For purposes of description the specimens have been classified on an anatomical basis, that is, according to the portion of vertebral column chiefly involved.

Injuries to Cervical Region of the Spine.—There are ten specimens in the Collection showing injury to the cervical vertebræ. It is interesting to note that only one of these shows an injury to the axis (comparatively slight), and none show injury to the atlas. The majority of injuries are those of the four lower cervical vertebræ. This may be explained by the fact that the specimens are from cases which reached at least an advanced base hospital. The higher and more rapid mortality in cases of injury to the proximal vertebræ prevented the cases from reaching the collecting centre. It is also to be noted that none of these show a perforating (through-and-through) injury in which the spinal cord would have been entirely cut off. The injuries are chiefly due to tangential blows where it is probable that considerable portions of the cord were still intact, enabling life to continue for several days or weeks.

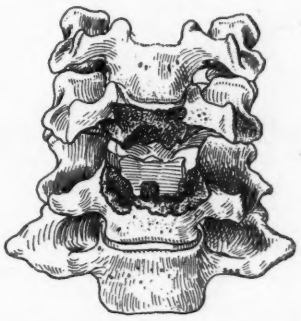


FIG. 63.—No. 3.24. Anterior surface of cervical vertebræ, showing partial destruction of the bodies of the 5th and 6th vertebræ.

In specimen No. 3.24 (*Fig.* 63) the bodies of the fifth and sixth cervical vertebræ and intervening disc have been almost completely destroyed by a glancing blow from a bullet which entered the pharynx and made an exit near the spine of the 3rd dorsal vertebra. The soldier was wounded on July 15, 1915. He developed a paraplegia with some loss of

sensation, and died on July 24; an abscess was found in the spinal canal at the site of the injury, which involved the cord.

Specimen No. 3.21 (*Fig.* 64) shows a fracture of the transverse and articular processes on the left side of the 3rd cervical vertebra caused by a bullet. The missile apparently came from behind, carrying away the tip of the spinous process of the axis, and the processes on the left side of the 3rd vertebra. A portion of the left pedicle has also been destroyed. Spinal meningitis developed, causing death.

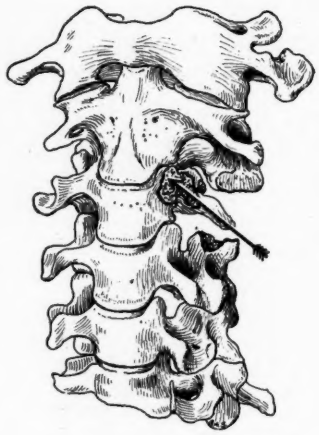


FIG. 64.—No. 3.21. Cervica vertebræ, showing fracture of transverse and articular processes on left side of 3rd vertebra.

Injuries to the Dorsal Vertebræ. — Specimen No. 3.37 (*Fig.* 65) is an interesting one showing the extensive injury which may be produced to the spine by a rifle bullet. The soldier was apparently lying down, and the missile, striking the spine of the second dorsal vertebra, travelled along the line of the vertebral column, and shattered the pedicles and the spinous and left transverse processes of all the dorsal vertebræ from the 2nd to the 9th, making its exit in the region of the 9th. The missile evidently at no point entered the spinal canal. The bodies of the 3rd to the 9th dorsal vertebræ, inclusive, show complete vertical fracture. A history of this case is not available.

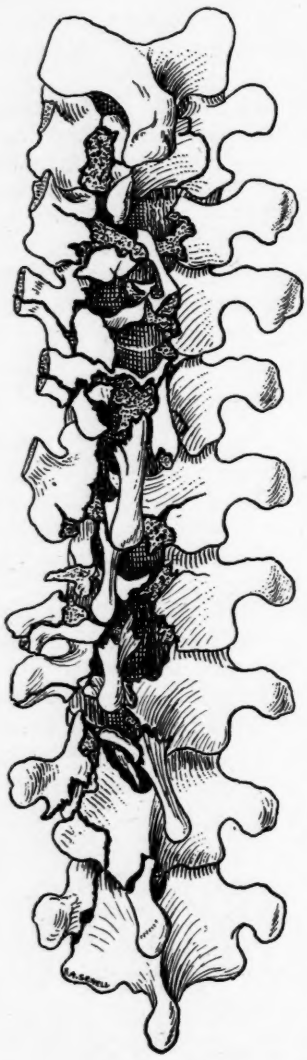


FIG. 65.—No. 3.37. Dorsal portion of spine, showing extensive fracturing of pedicles and spinous processes.

Specimen No. 3.3622 (*Fig.* 66) is an example of a trans-spinal injury in which the spinal cord was entirely cut across. The missile, a bullet, passed in an oblique direction, ente ing above the left clavicle and emerging on the back, to the right of the 10th dorsal spine. It struck the left pedicle of the 4th dorsal vertebra, fracturing the head of the rib, entered the spinal canal, and made an exit in the region of the right articular process of the same vertebra, shattering the right transverse process and lamina. The soldier was wounded on Nov. 23, 1917, and died on Dec. 5. He had paralysis below the waist line, with retention of urine and fæces. There was also a left hæmothorax, with an empyema on the right.

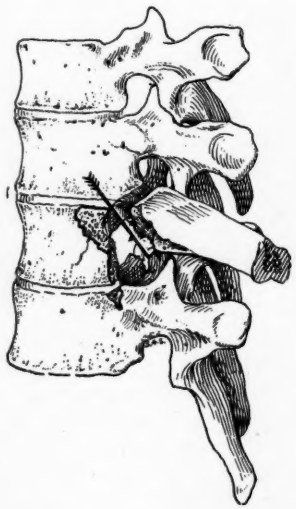


FIG. 66.—No. 3.3622. Oblique trans-spinal injury of 4th dorsal vertebra. Aperture of entrance is shown, with portion of left 4th rib *in situ*.

Specimen No. 3.38 (*Fig.* 67) exhibits a more extensive injury than that seen in No. 3.3622 (*Fig.* 66). The missile, a rifle bullet, struck the 12th dorsal vertebra at about the same point as in No. 3.3622, and made its exit between the left articular

process and spinous process. It apparently just passed through the roof of the spinal

FIG. 67.—No. 3.38. Posterior view of the three lower dorsal and two upper lumbar vertebræ, showing extensive fracture of the vertebral arches of 11th and 12th dorsal vertebræ. The arrow indicates direction taken by the missile.

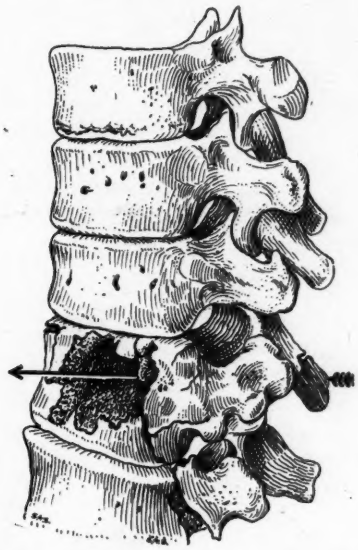


FIG. 68.—No. 3.3816. Left lateral view of lower dorsal vertebræ and 1st lumbar vertebra, showing trans-spinal injury with perforation of the body of 12th dorsal vertebra. The arrow indicates direction taken by missile.

canal. The head of the 12th rib, and the right pedicle, lamina, and spinous process of the 12th dorsal vertebra, are shattered, and also the inferior left articular process and lamina of the 11th dorsal vertebra. No history of this case could be obtained.

Specimen No. 3.3816 (*Fig.* 68) shows a trans-spinal injury of the 12th dorsal vertebra in which the vertebral arch escaped with but slight injury, while the body has been perforated and fractured. The missile, a rifle bullet, entered the spinal canal through the 11th interlaminar space, just to the right of the 11th spinous process, perforated the body, and ultimately lodged beneath the left nipple. The spine of the 11th dorsal and the left pedicle of the 1st lumbar vertebræ have been fractured by indirect force. The soldier was wounded on Oct. 10, 1917, and admitted to hospital the next day with complete paraplegia and incontinence of urine and fæces. He died on the 22nd from sepsis and infected hæmothorax. The spinal cord was found to have been completely severed at the level of the injury. It has been preserved and mounted in the 'wet' series of the War Office Collection.

FIG. 69.—No. 3.421. Posterior surface of the upper part of the lumbar spine, showing a gunshot injury of the body of the 1st lumbar vertebra in which a laminectomy had been performed, followed by partial repair.

Injuries to the Lumbar Portion of the Spine.—In the War Office Collection there are 15 specimens with gunshot injury to the lumbar vertebræ. In 5 of these the injury to the spine is associated with an injury to the pelvic bones, the missile first striking the pelvis in each case. In these specimens the pelvis has been mounted with the sacrum and lumbar vertebræ.

No. 3.421 (*Fig.* 69) is an instructive specimen. The patient apparently lived for some weeks, and after injury a laminectomy had been performed on the 1st and 2nd lumbar vertebræ. The missile entered the spinal canal from behind, and penetrating the body of the 1st lumbar vertebra, destroyed and shattered the right half, and produced a vertical fissure through the posterior portion of the body of the 2nd lumbar vertebra. Healing has taken place, with the laying down of an irregular callus plate on the right side of the body of the 1st lumbar, and between it and the body of the 12th dorsal vertebra. The right transverse process, which had been fractured, has been re-united, and the fissure of the body of the 2nd lumbar has been filled in. The bony margins of the laminectomy wound show delicate callus points and some absorption. No further history could be obtained.

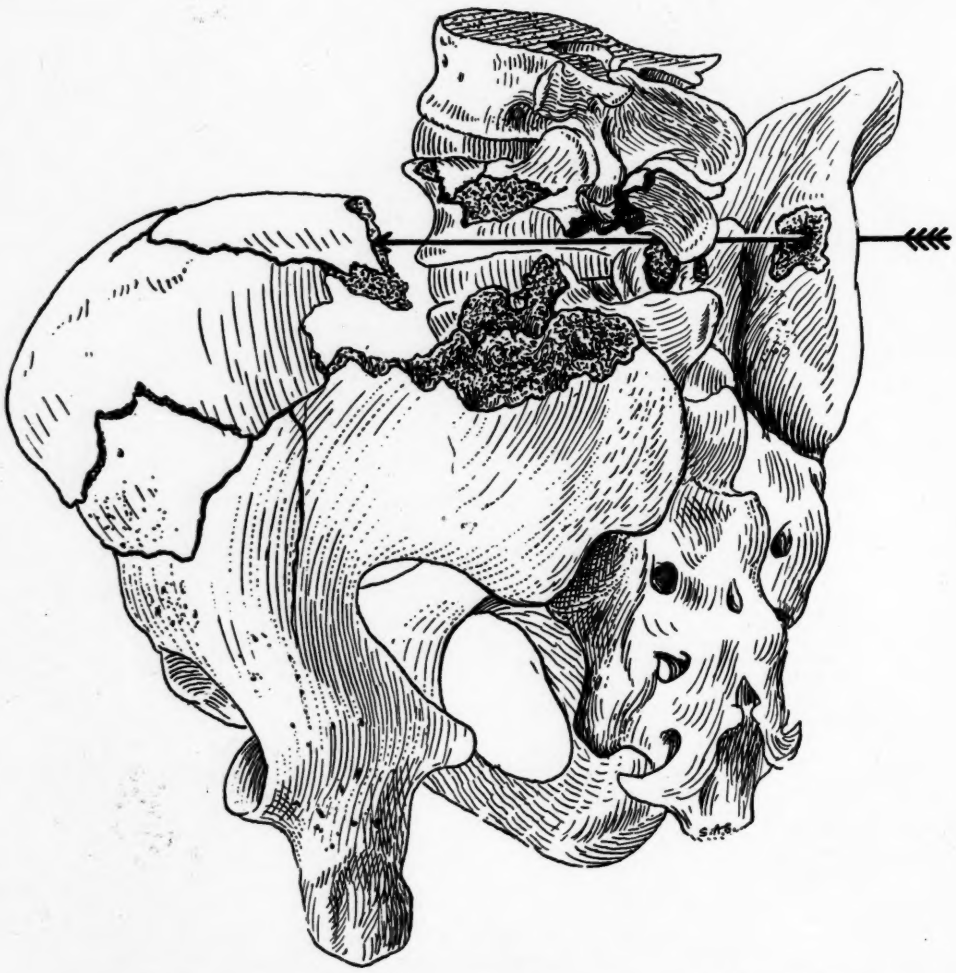


FIG. 70.—No. 3.4815. Posterior surface of iliolumbar region, showing extensive injury to pelvis, 5th lumbar vertebra, and sacrum. The direction taken by missile is indicated by the arrow.

Specimen No. 3.4815 (*Fig.* 70) is one of the iliolumbar region showing the injuries produced by a bullet entering from the side. The wound of entrance was in the upper part of the right buttock, and the wound of exit at about the same level of the left buttock. The soldier was admitted to No. 3 General Hospital, Aug. 29, 1918. There was fæcal discharge from the wound in the left buttock, paraplegia, and incontinence of urine. He died on Sept. 8 from sepsis with acute cystitis. Note in the specimen the marked difference

in the extent of injury to the right and left ilia. The aperture of entrance, right ilium, is circular, 1 cm. in diameter, and its centre is 15 mm. from the posterior margin of the iliac crest, and 4 cm. above the posterior inferior spine of the right ilium. The missile passed through the bone, forming a circular canal with no fissures except for slight marginal fracture at the medial end. The spinous process of the 5th lumbar vertebra is fractured entirely across at the base, and the arch of the same vertebra is shattered; its inferior portion on the left side, left inferior articular process, and left transverse process are missing. There is some fissuring of the posterior surface and superior portion of the lateral surface of the sacrum on the left side, with loss of an irregular portion of cortex 35 by 35 mm. The missile apparently struck the posterior third of the left iliac crest a glancing blow. The left ilium—superior two-thirds—is broken into several large portions, of which the posterior end of the crest, 6 by 3 cm., is missing. This specimen is instructive in showing extensive injury to the pelvis and sacrum as well as an injury to the lumbar vertebræ.

In a detailed study of the specimens of spinal injury, certain features of importance present themselves. It is noted that in the majority of injuries to the vertebral arch, one finds fissuring of the vertebral body; while in injuries to the body, even when there is perforation, there is seldom any marked fracturing of the arch or processes.

Specimen No. 3.37 (*Fig.* 65) is an excellent example of this secondary fissuring of the body. The history of this specimen is very incomplete, and we have been in considerable doubt as to the mechanism of the injury. We are indebted to Colonel Thorburn and Major Richardson for a probable explanation as to how it was produced. At first we thought that the bullet must have hit the various processes which have been fractured; but the probable explanation is that the fractures were to a large extent produced by the carrying away of the soft parts, thereby tearing off the processes. Also, it is possible that the lateral recoil of the soft parts may have played a part, very much in the way that we have pointed out in the injuries to the mandible and in certain fractures of the calvaria.

Another point we have noticed is that the vertebral body is particularly resistant to direct injury by missiles, even when perforated, as compared with the destruction seen in long bones. This may be explained by the fact that the body is, to a large extent, cancellous, with only a narrow cortex of dense bone. In specimen No. 3.3816 (*Fig.* 68) the body has been completely perforated, yet there is no fissuring except for the marginal bevelling of the cortex at the aperture of exit of the missile.

(*To be continued.*)

A STUDY OF GUNSHOT WOUNDS OF THE BRAIN.

By Captain ALAN NEWTON, A.A.M.C., and Captain A. E. BROWN, A.A.M.C.

Probably more fallacious opinions have been expressed about the management of penetrating head injuries than has been the case in any other department of war surgery. It is believed even now, for example, that a preliminary delay in operating, so far from being harmful, may on the contrary be an advantage in these cases. Why head injuries should be supposed to differ from all other war wounds in this respect is difficult to understand. There is also a general impression that the after-results are so deplorable that the time spent in operating upon brain injuries would be better employed in the treatment of more hopeful cases. The technique has been extraordinarily varied, and frequently extremely crude. It has not been generally realized that the greatest gentleness is necessary in any intracranial manipulation.

Many of these fallacies have been exposed by Cushing,[1 2] who has recently published a masterly study of 250 cases of head wounds, and has done so much to improve the results of treatment of these injuries. It would be, therefore, a work of supererogation to attempt to expose them again. Some lessons, nevertheless, have been made clear even in this short series, and attention will be directed to them.

This paper comprises a study of 67 unselected consecutive cases of craniocerebral wounds, and a description of the technique employed. This has been based upon that elaborated by Cushing, and the cases have been grouped in accordance with his classification for the sake of uniformity. As many of the cases were admitted during periods of great pressure of work, the records are, in many instances, very incomplete. There are, in short, "a hundred faults in this thing," and we are forced, in its vindication, to adopt the somewhat truculent excuse of Mercerus[3]: "If I have spent my time ill to write, let not them be so idle as to read."

Literature.—As this paper was written in France, access to the literature of the subject has been difficult. References to the work of various authors will be found throughout the text.

Material.—Of the total 67 cases, 32 were operated upon at a casualty clearing station late in 1917. A further series of 35 cases were treated at a base hospital in the latter half of 1918. During 1917 the majority of the cases of penetrating head injuries were operated upon at a casualty clearing station; but in 1918, for military reasons, all these cases were transferred direct to the base for operation. It will thus be seen that the same types of injury are included in both series, though, of course, the base hospital cases were more infected, and were, on the whole, less severe, as the more extensive injuries did not survive to reach the base. The time which had elapsed before admission is indicated in each case report.

Technique.—As soon as possible after admission the patient is seen and a brief neurological examination made. A radiogram of the head is then taken. This step should never be omitted; it gives information of the greatest value. The projectile, if present, is localized, and—of even greater importance—the extent and direction of indriving of bone are indicated.

X-ray Technique.—The radiographic work in these cases was done throughout with the usual army outfit—a 12-in. Butt coil, dreadnought interrupter, and Macalaster-Wiggin tube, working with a spark-gap of 7 inches and at a distance of about 40 cms. from the plate. The available primary current was 150 volts from accumulators, with an average of 4 ma. through the tube. It will be seen, therefore, that though the outfit was sufficient to produce fair standard results, none of the special advantages required

for finer points of radiographic diagnosis were available. The exposures were 30 to 40 seconds for a lateral view of the head, and 40 to 45 seconds for the anteroposterior view.

A careful preliminary screen examination was made in all cases in which the presence of a lodging foreign body was probable or possible; but was not accepted as negativing definitely the presence of a small body in the region of the base of the skull or the deeper parts of the face. Therefore, in all these cases, the patient was placed in position for localization of the suspected foreign body, and the first plate of the localizing system (either two-plane or stereoscopic plates) was exposed, and immediately developed, the patient and tube remaining in position meanwhile. In the great majority of cases this practice was quite feasible, but with a very stuporous or restless patient the two plates required by the system must both be taken with as little delay as possible. If a foreign body is detected in the first plate, the second plate is taken and the two are studied.

The counter-claims of stereoscopic plates and of two-plane plates as a means of localization of the foreign body, depend upon the accuracy with which the planes can be determined on the one hand, and upon the practice and skill acquired in interpreting the stereo on the other. In the first plate the whole head is included in the negative, and also in the second if a foreign body is found. But if the first plate shows only local damage to the skull, the second plate is taken with a conical extension diaphragm in position. The diaphragm we use is 6 inches long, and with a diameter increasing from 2 to 3 inches. This necessarily cuts down the field largely, but greatly increases the sharpness of the detail. Small indriven fragments of bone can be shown in this way which would be completely missed with an open diaphragm. A stereoscopic pair of plates with the extension diaphragm in position will reveal the number and relations of the fragments in a way that no other method will. For this purpose, both positions of the tube should be set visually by means of the screen, and the tube shift is $2\frac{1}{2}$ to 3 cms.

Grazing wounds of the scalp, with no lodging foreign body and probably only local damage to the skull, are taken directly with the extension diaphragm in position; and a larger field negative is taken later if required.

Immobilization of the head is secured by placing across it a 3-inch bandage weighted at the ends by small sandbags, which hang over the sides of the table. The plate is placed between the head and the bandage. The head is raised slightly in both anteroposterior and lateral planes, to ensure correctness of plane, being rested on an ordinary 1-ft.-square *x*-ray plate box. As the need for accurate reproduction of previous *x*-ray positions has not arisen, no mechanical apparatus for this purpose has been employed.

Anæsthesia.—Early in the series a general anæsthetic was the routine practice. This was soon abandoned, and in the great majority of cases local anæsthesia has been employed.

The advantages of local anæsthesia in cranial surgery were first described by Martel[1] in 1913. His methods have recently been explained by M. E. Rochard, and at the ensuing discussion at a meeting of the Société de Chirurgie, Duval and others agreed upon their value. Cushing attributes the improvement in his results in part to the adoption of local anæsthesia. The advantages may be briefly summarized as follows:—

1. The patient can be placed in any suitable position, and this position can be changed during the operation.

2. There is less hæmorrhage from the scalp, and the elevated position of the head diminishes the venous oozing from the brain. This has been pointed out by Martel, who states that ether narcosis increases cerebral hæmorrhage owing to the increase in arterial tension. Ether also provokes an increase in the secretion of cerebrospinal fluid, and so augments the intraventricular pressure. (Cushing.)

3. Post-operative vomiting is avoided.

4. Cleansing of the track of the missile is facilitated by directing the patient to cough gently at a suitable time.

It is not always possible to employ this method with very restless patients. One such case occurred in this series. The patient, from the time of admission, threw himself about

on the bed and refused to be comforted. Warmed ether was therefore administered by a Shipway apparatus. This is the general anæsthetic of choice.

Technique of Injection in Local Anæsthesia.—One hour prior to the operation a hypodermic injection of 1 c.c. omnopon and scopolamine is given (corresponding to $\frac{1}{3}$ gr. morphia). The scalp is then completely shaved; this must be done carefully in order to avoid the common error of leaving loose hair scattered about on the surface of the scalp, which is then prepared with ether, followed by a 3 per cent solution of picric acid in rectified spirit.

A Gray's syringe is employed for the injection of the local anæsthetic, which is a $\frac{1}{2}$ per cent solution of kerocain to which has been added adrenalin in the proportion of 30 drops to 50 c.c. The injection is made at a convenient distance from the wound in such a manner as to encircle the proposed lines of incision. A small quantity is first injected immediately under the skin, followed by a much larger injection under the pericranium. This latter injection raises a wheal about half an inch in height. It is usually possible to proceed at once to the operation.

Operative Technique.—The operative technique has been constantly modified and improved, and varies considerably according to the requirements of the individual case. It is useless to attempt to do modern head surgery with obsolete instruments. Trephines and old-pattern rongeurs belong now to surgical museums, and have been entirely replaced by Hudson or Doyen burrs, Montenovesi's rongeurs, and parrot-bill biting forceps. These instruments are essential.

The following summary indicates the general steps of the operative treatment: (1) Excision of wound of scalp; (2) Removal of fracture *en bloc*; (3) Removal of bone fragments and projectile from brain by the catheter method; (4) Irrigation of wound of the brain; (5) Careful suture of the scalp wound in two layers, with or without drainage or B.I.P.P. pack.

1. Excision of the Wound.—This must be thorough. If an infected area is left it will reinfect the whole suture line. Gray[5] has shown that after very extensive excisions the wound can be sutured completely by the use of well-planned plastic flaps. Where possible the wounds have been excised by including them in the course of a straight or curved incision. In cases where, owing to the extent of the wound, this has not been possible, Cushing's tripod incision has been employed.

2. Treatment of the Skull Fracture.—At one time the usual plan was to make a burr opening close to the fracture, and then expose the dural wound by removing the edge of the fracture with a rongeur. Cushing first introduced the method of *en bloc* removal. This method has the following advantages: (*a*) The wound in the bone which contains damaged and infected tissue is completely and cleanly excised.* (*b*) When the fracture is near a venous sinus the whole field is exposed at once by an *en bloc* removal, so that hæmorrhage can be immediately controlled. (*c*) It is frequently possible to piece together the indriven fragments like a jig-saw puzzle and so be certain that all the fragments have been removed (*see Fig.* 85).

In fractures near the base of the skull it is not always possible to remove the fracture *en bloc*, but this is the method of choice. The technique consists in making two or more burr openings as near as possible to the fracture, and then uniting these openings by a rongeur. The whole fracture can then be lifted out in one piece.

3. Treatment of the Wound in the Dura.—Unless the dural wound is very ragged it is not excised. In four cases the dura was sutured, and in one case, where a large dural defect with little cortical damage was found, this was repaired by a graft from the temporal fascia. Such procedures are only wise in cases which are operated upon soon after the infliction of the wound.

Willems[6] has recently reported a series of 46 cases of craniocerebral wounds, in 18 of which the dura was sutured. These 18 cases recovered.

4. The Cerebral Wound.—Much time and more patience are required for the successful cleansing of the cerebral wound if this be at all extensive. All the indriven fragments must be removed and, if possible, the projectile should be extracted. The

practice of searching for bone fragments in the brain with the finger is one to be strongly condemned. Even when performed with great care it must result in increased damage to the brain. All fragments should be localized by a rubber catheter to which is attached a Carrel-Gentil syringe. With such a catheter very minute fragments can be detected. During this exploration the whole wound is irrigated with saline or Dakin's solution, and some of the smaller fragments are removed in this way. The greater number of fragments are more easily removed by a sinus forceps introduced in the direction and to the depth indicated by the catheter. In several cases in this series, one to one and a half hours were spent in the patient removal of fragments. The projectile when present should be removed if possible. A magnet is very useful for this purpose, but unfortunately was not available for use in this series. In one case Ferguson's[7] apparatus was employed with success in the localization and removal of a metallic fragment in the frontal lobe.

With reference to the advisability of making a prolonged search for the projectile, Monprofit and Courty[8] state that wounded men with a retained projectile have no higher mortality than those cases in which the projectile has passed through, and that the mortality where the projectile has been immediately extracted does not seem less than in similar cases where the projectile was not extracted.

Marie[9] has stated that he observed 31 old cases of intracranial projectiles, in 29 of which there was absolute tolerance, and in only 2 cases were there epileptiform crises.

Cushing believes that retained bone fragments are more likely to produce subsequent complications than are metallic fragments, though these are infected and should always be removed if possible.

The disorganized brain and blood-clots are removed by irrigation, Dakin's solution being usually employed. The irrigation should be thorough, and—a point of even more importance—not too forceful. Vigorous irrigation spreads infection.

Great care is necessary to achieve absolute hæmostasis. Gentleness in manipulation is essential. Bleeding points should be controlled by ligatures of fine catgut, or by a small piece of muscle, which is a most efficient hæmostatic agent. Cushing's wire clips are very useful, but were not at our disposal. Wounds of a venous sinus were treated by fascial or muscle grafts.

5. Suture of the Wound.—At first the wounds were closed by through-and-through silkworm-gut sutures passing through all the layers of the scalp. This is a rough method of suture, involving inaccurate apposition, undue compression of tissues, and frequently producing infection around the suture holes. It has been replaced by suture in two layers, in which the epicranial aponeurosis is sutured by catgut and the skin is then united by horse-hair ; these sutures are removed on the fourth day. This method ensures accuracy of apposition without undue tension, and so decreases the incidence of wound infection.

Drainage.—This depends upon the extent of the injury and the degree of infection, i.e., the time which has elapsed since the infliction of the wound. In those cases in which the wound was small and the operation early, no drainage was necessary. In more extensive injuries a glove rubber drain was employed for the first twenty-four to forty-eight hours. In cases in which the operation was not performed for two to five days after the infliction of the wound this method was not satisfactory, as it frequently failed to prevent the spread of infection in the wound. Bacteriological examination in these cases revealed the presence of anaerobic bacilli, streptococci, and numerous other organisms. In this type of case a B.I.P.P. pack proved of great value.

The B.I.P.P. Pack.—This pack consists of a thin strip of gauze soaked in paraffin and then impregnated with bismuth, iodoform, and paraffin paste (Rutherford Morison's formula). The pack is placed lightly in the wound in such a manner that all recesses superficial to the cerebral wound are filled and no dead spaces remain. The wound is then sutured over the pack, one end of which protrudes through the incision. The pack is removed on the third day and replaced by a smaller one. Three days later the latter is removed, and the aperture through which the pack protruded is closed by secondary suture or allowed to heal by granulation. This method has proved of the greatest service in infected cases. The pack acts by obliterating all dead spaces, thus decreasing the risk

of infection, and, owing to its oily nature, by preventing adhesion of surfaces and consequent pocketing. Drainage is quite free and is usually slight in quantity, and—an important point—reinfection from the skin is prevented. Many of the severely infected cases healed uneventfully without the formation of a cerebral hernia.

The difficulty of treatment of brain injuries which had been neglected for several days was doubtless responsible for the introduction of the so-called open-flap method of treatment of the penetrating head wounds—a method in which the skin flaps are sutured back, thus widely exposing the cerebral injury. A hernia cerebri forms, and later, in successful cases, the flaps are re-sutured into place. Our experience has been that the brain injury, if satisfactorily cleansed at the operation, will heal uneventfully if reinfection be prevented. The open-flap method simply invites this reinfection, and therefore cannot be too strongly condemned. The following case will illustrate the B.I.P.P. pack method.

Case 1.—Pte. G. N. B. Admitted three days after the infliction of a wound in the left post-parietal region. The wound was dirty and ragged. The patient was stuporous. There were no other abnormal neurological signs. *X*-ray showed a depressed fracture, with indriving of bone fragments to a depth of 1½ inches.

Operation. — Fracture removed *en bloc*, numerous small fragments removed from brain. B.I.P.P. pack. Suture in two layers. Bacteriological report on indriven bone fragments says: anaerobic bacilli type *B. Welchii*, long-chain streptococci.

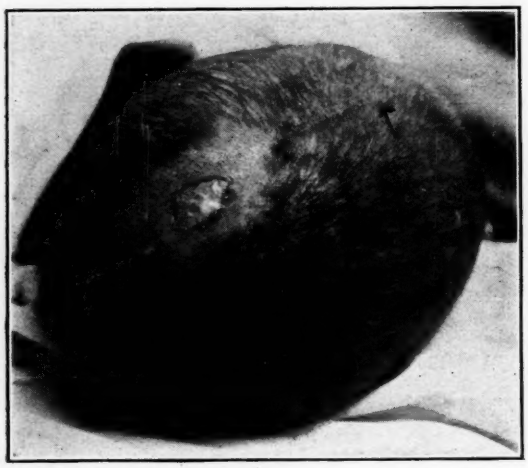


FIG. 71.—*Case* 1. Granulating area after removal of B.I.P.P. pack.

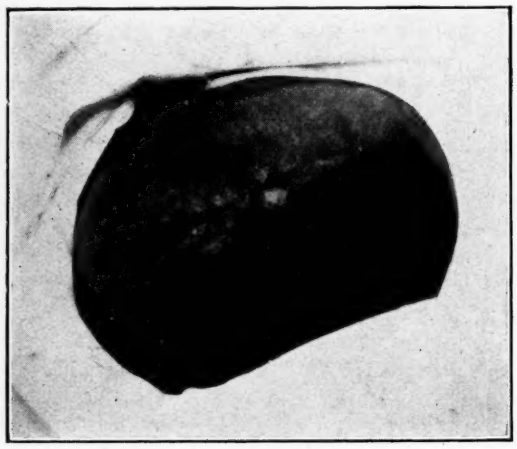


FIG. 72.—*Case* 1. Seven days after secondary suture.

After-treatment.—Three days after operation the pack was removed and a smaller pack inserted. This pack and the sutures were removed two days later. Wound remained clean, and fourteen days after operation the small granulating area was closed by secondary suture (*Figs.* 71, 72). *X*-ray showed all depressed bone removed.

The patient was quite normal three months after the operation.

After-treatment.—The wound is dressed with B.I.P.P. gauze. This dressing does not adhere to the incision, and at the same time does not easily become displaced. Daily dressing of the wound is necessary, and should be performed by the surgeon himself, in order that due warning may be obtained of the onset of any infective complication.

Treatment of Cerebral Hernia.—The only satisfactory treatment of this condition is prophylactic. A thorough and efficient cleansing of the wound at the operation, i.e., a complete removal of all damaged tissues and foreign bodies, will prevent the formation of a hernia. No satisfactory treatment of a rapidly increasing soft hernia has been devised. Lumbar puncture is sometimes useful, but the majority of these cases terminate fatally. In the more slowly developing herniæ treatment is not so difficult. One such case occurred in this series. It subsided in the course of three weeks, during which it was dressed with B.I.P.P. gauze and light pressure applied by a bandage.

The Treatment of Superficial Infections.—Superficial infections were treated by irrigation with Dakin's fluid. This was introduced with a syringe every four hours. A Carrel tube was found unsatisfactory in head wounds. It was frequently pulled out by the patient, and, further, interfered with the healing of the wound by its pressure.

CLASSIFICATION OF CRANIOCEREBRAL WOUNDS.

It has been the custom to classify these injuries according to the type of the skull fracture present. This method should be abandoned, for it fails to indicate the extent of the cerebral injury. The fallacy has been exposed by Cushing, whose classification has been adopted in this paper, with the addition of a separate group for wounds of a venous sinus.

Cushing states that there are doubtless imperfections in his scheme, and that other subdivisions may be better, but that it is thrown out merely as a temporary working basis on which cases may be recorded for purposes of comparison without too much elaboration.

CLASSIFICATION OF CASES AND RESULTS.

GROUP.	DESCRIPTION.	CASES.	DEATHS.	MORTALITY PER CENT.
I	Local depressed fracture of various types with puncture of the dura	12	0	0·0
II	Wounds, usually of gutter type, with depressed bone fragments driven into the brain ..	21	3	14·2
III	Wounds of penetrating type, with lodgement of projectiles and bone fragments	11	6	54·5
IV	Wounds involving the ventricular system	9	9	100·0
V	Wounds involving both the brain and an air sinus	4	2	50·0
VI	Through-and-through wounds of the skull	6	1*	16·6
VII	Wounds involving a venous sinus	4	0	0·0

* Two end-results uncertain—probably died.

Group I.—LOCAL DEPRESSED FRACTURES OF VARIOUS TYPES WITH PUNCTURE OF THE DURA.

In this group are placed those cases in which some fragments of the depressed inner table have been driven through the dura. There is no cerebral hernia, as the skull, though fractured and depressed, still forms a complete covering. The cerebral laceration is slight, but is frequently surrounded by an area of contusion which may give positive signs on neurological examination.

The operative technique is not difficult, as there is no extensive indriving of bone fragments. It is usually possible to suture the wound in the dura in these cases.

Case 2.—Pte. W. S.—Admitted five hours after the infliction of the wound, which was small, and situated in the right post-parietal region. There had been no loss of consciousness, and the patient had been able to walk to the dressing station. There were no abnormal signs on neurological examination.

Operation.—The wound was excised and a small depressed fracture removed. A dural laceration ½ inch in length was exposed, with subjacent superficial cortical laceration. The dura was sutured with fine catgut sutures, and the wound closed without drainage. Healing was uneventful.

This minor type of injury is less frequent than that in which, in addition to the small cortical wound, there is an area of contusion giving rise to disturbances of consciousness, of speech, or of vision, or to interference with sensori-motor functions.

This is illustrated in the following case, in which a hemiplegia was present.

Case 3.—Pte. A. B. Admitted ten hours after injury. Small wound in the right parietal region. Patient was unconscious for two hours, and is still irritable. A left hemiplegia is present.

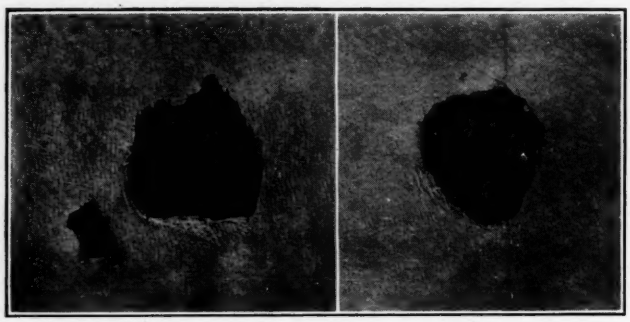
The deep reflexes are exaggerated and superficial reflexes absent. Babinski reflex was elicited on the left side.

Operation.—A large depressed fracture of the right parietal bone was removed. There was a small extradural hæmorrhage from a diploic vessel. A dural wound ¾ inch in length was sutured, and the wound was then closed without drainage.

The wound had healed and the hemiplegia had completely disappeared fourteen days after the operation.

In another case both sensory and motor centres were involved.

Case 4.—Pte. A. M. Admitted two days after injury, with a glancing wound in the parietal region immediately to the left of the mid-line. *X*-ray examination showed a linear fracture of the outer table. One small depressed fragment of the inner table.



A. *B.*

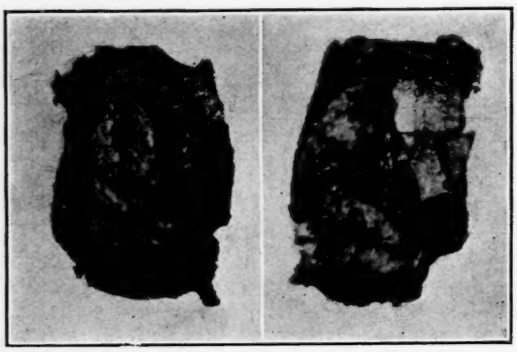
FIG. 73.—*Case* 4. *A*, Outer table. Separated fragment removed from brain. *B*, Inner table mosaic reconstituted.

Neurological Examination.—Motor: normal range but greatly diminished power in all movements of right lower limb. Sensory: defective localization of touch and loss of sense of muscle position in right lower limb. Reflexes: right superficial abdominal and right cremasteric reflexes absent. Right knee-jerk increased. Flexor plantar reflex on left. No reflex elicited on right.

Operation. — Wound excised. Fracture removed *en bloc* (*Fig.* 73). The small indriven fragment had penetrated the dura. It was removed, and the wound sutured, with glove-rubber drainage.

Healed well. The abnormal neurological signs had completely subsided at the end of four weeks, when the patient was able to walk normally.

Attention has frequently been directed to the fact that a linear fracture of the outer table may be accompanied by a much more extensive fracture of the inner table. This is illustrated by the following case, in which also a hemiplegia was present.



A. *B.*

FIG. 74.—*Case* 5. *En bloc* removal of bone. *A*. Outer table. *B*. Inner table.

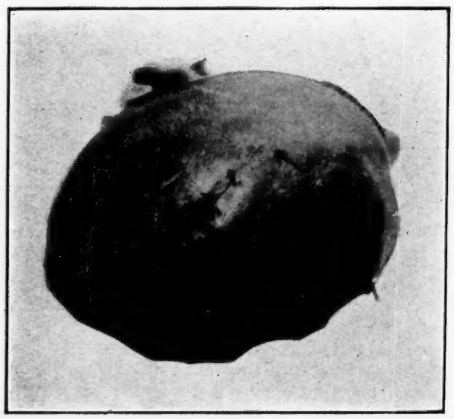


FIG. 75.—*Case* 5. Wound seven days after operation.

Case 5.—Pte. J. H. Admitted two days after infliction of wound. This was glancing in type, and was in the left parietal region.

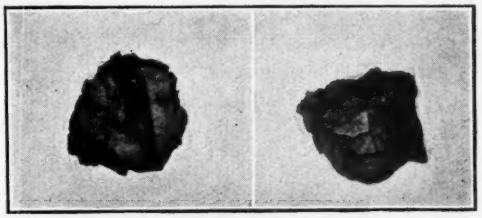
Neurological Signs.—The patient was irritable and strongly resented examination. A right hemiplegia with absent superficial and exaggerated deep reflexes was present. A Babinski reflex was elicited on the right side.

X-ray Examination.—Small depressed fracture.

Operation.—Depressed fracture removed *en bloc* (*Fig.* 74). The depressed fragments had lacerated the dura. The wound was sutured in two layers, and healed without incident (*Fig.* 75).

The hemiplegia rapidly disappeared, and six weeks after the operation the patient was able to walk well.

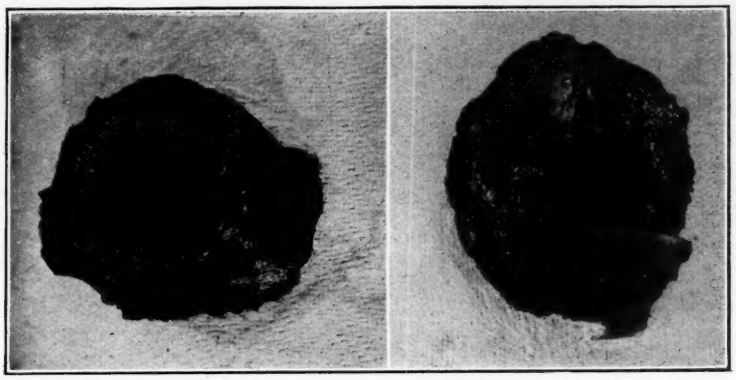
Occasionally the reverse holds true. *Fig.* 76 demonstrates an extensive fracture of the outer table, with merely a small depression of the inner table, which had not caused any laceration of the dura. In this case, it must be noted, the skull was exceptionally thick.



A. *B.*

FIG. 76.—*A.* Deep fracture of outer table. *B.* Small depression of inner table.

Nor is it possible to predict the effect produced by a projectile on the skull. This will be seen by a study of the three following cases, in which metallic fragments have lodged in the bone. In two instances the inner table was fractured in a typical manner, whilst in the third the projectile penetrated the skull without causing much comminution.



A. *B.*

FIG. 77.—*Case* 6. *A.* Outer table; shrapnel bullet embedded. *B.* Mosaic of inner table.

Case 6.—Sgt. G. H. B. Admitted thirty-six hours after the injury with a small punctured wound in the left frontal region. There was no loss of consciousness. The patient was evacuated to the base as a walking case. No abnormal signs were noted on neurological examination.

X-ray Report.—Shrapnel bullet embedded in outer table, depressed fracture of inner table.

Operation.—Wound excised by curved incision. Removal of fracture *en bloc* (*Fig.* 77). Wound one inch in length in dura, with extensive laceration of the cortex. Wound sutured with glove-rubber drain. Healed uneventfully (*Fig.* 78).

FIG. 78.—*Case* 6. Seven days after operation.

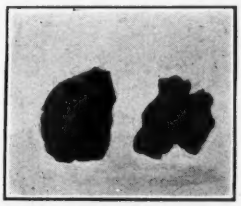


FIG. 79.—*Case* 7. Fracture removed *en bloc*. Showing fragment in outer table, and depressed and separated portion of inner table.

Case 7.—Pte. J. T. Admitted two days after injury, with small ragged wound in left occipital region; no abnormal signs on neurological examination.

X-ray Report.—Small metallic fragment in outer table. Detached fragment of inner table.

Operation.—Removal *en bloc* of fracture. There was a complete detachment of a portion of inner table (*Fig.* 79). This fragment had lacerated the dura. The wound was sutured and healed uneventfully.

Case 8.—Pte. E. In this case the projectile had fractured the occipital bone without causing much comminution, and was found superficial to the dura, in which there was a small laceration (see *Fig.* 80). It was curious that a velocity sufficient to cause a clean penetration of the skull failed to carry the projectile into the brain.

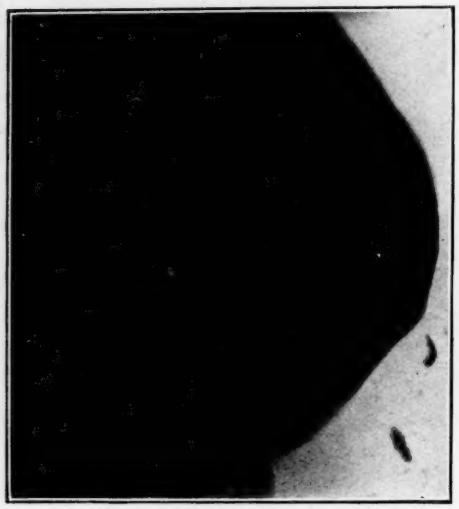


FIG. 80.—*Case* 8. Penetration of projectile without comminution.

In the following case the condition was complicated by a middle meningeal hæmorhage. An indriven fragment had torn the dura, lacerating at the same time the anterior branch of the middle meningeal artery.

Case 9.—Pte. G. K. Admitted six hours after injury, having a ragged wound in the left temporal region.

Neurological Examination.—Patient stuporous. Right hemiplegia present. Left pupil smaller than right.

Operation. — Wound excised, and depressed fracture of squamous temporal bone removed. Large extradural clot evacuated. Laceration of dura and partial division of anterior branch of middle meningeal artery. Artery ligated and dura sutured. There was good expansion after the removal of clot. Wound sutured with glove-rubber drain. Healed by first intention. Evacuated to base three weeks later. Hemiplegia subsided.

The next case is of interest in that a large dural defect was repaired by a graft taken from the temporal fascia. This was done because there was only a superficial injury to the cortex, and it was thought that in this way it might be possible to avoid an extensive cortical adhesion.

Case 10.—Gnr. B. Admitted five hours after injury.

On Admission.—Small superficial wounds of right shoulder, right hand, and left ankle. Glancing wound in left parietal region, and a larger, more ragged wound in right parietal region. Patient states that he was unconscious for a few minutes; but on admission he was alert and exhibited no abnormal neurological signs.

Operation.—There was a depressed fracture in the left parietal region, which was removed. On the right side there was a depressed fracture of the parietal bone. The fragments had caused an extensive laceration of the dura, 1 by 1½ inches in extent. There was only a superficial laceration of the cortex. A graft taken from the temporal fascia was tucked in under the dural edges and sutured in place. The other wounds were excised.

Subsequently the ankle wound suppurated, and two days later superficial infection occurred in the head wounds. This soon subsided, and the patient was evacuated.

Group II.—WOUNDS, USUALLY OF GUTTER TYPE, WITH DEPRESSED BONE FRAGMENTS DRIVEN INTO BRAIN.

These wounds are usually of a tangential nature, and are frequently accompanied by severe brain injury.

Velter[10] states that prognosis is particularly grave in tangential wounds, for, though the wounds themselves are apparently benign, the deep lesions may be considerable.

It would be more correct to state that the post-operative prognosis depends entirely on the operation. It is necessary to spend much time in a gentle search for all the indriven bone fragments, however minute these may be. If this complete removal be successfully performed, the patient will almost invariably get well. Cases in this group should recover, and failures are usually to be attributed to some defect in operative

technique. Naturally, the time which has elapsed since the infliction of the wound must influence the result. In some cases operated upon at the base, most formidable infection was demonstrated; but even in these cases successful results were obtained after careful cleansing of the wound and packing with B.I.P.P. gauze.

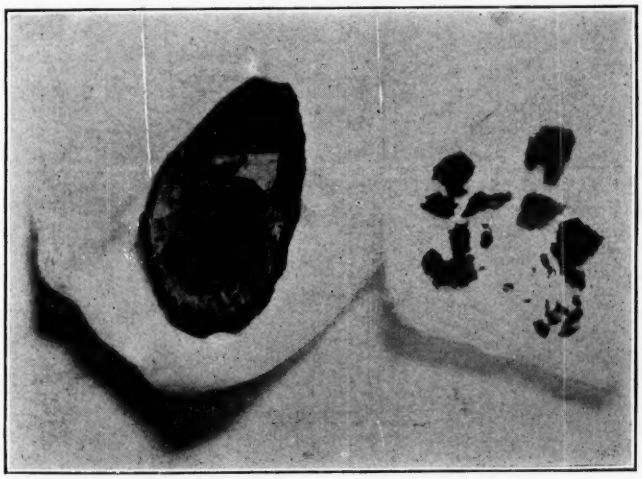
The following case demonstrates the difficulties attending successful treatment of cases of this group.

Case 11.—Pte. G. A. Admitted four days after the injury.

On Examination.—Lacerated wound in the left frontal region, through which projected offensive brain tissue. The patient answered questions in an irritable manner, frequently incorrectly. No other abnormal neurological signs were discovered. *X*-ray showed fracture of left frontal bone, with considerable loss of substance; indriving deeply into the frontal lobe of numerous small fragments (*Fig.* 81).

FIG. 81.—*Case* 11. Extensive indriving of fragments into frontal lobe.

Operation.—The fracture was removed *en bloc*. There was an oval defect in the frontal bone, 2 inches long by ¾ inch broad (*Fig.* 82). The subsequent search for bone fragments lasted for one hour. After these had been removed, the wound was freely irrigated and the skin sutured in two layers over a B.I.P.P. pack. The pack was renewed on the third day and removed on the sixth day. Healing was uneventful.



A. *B.*

FIG. 82.—*Case* 11. *En bloc* removal of fracture. *A*. Inner table roughly reconstituted. *B*. Outer table fragments.

Bacteriological Report (culture from indriven fragments).—Anaerobic bacilli, type *B. Welchii*, and type *B. sporogenes*, *Staph. aureus*, and the streptococci, short chains. The successful result, despite this bacterial infection, is to be attributed to the time spent in ensuring complete cleansing of the cerebral wounds.

In the following case it was necessary to excise a large ragged wound by the tripod incision. In this case there was also a hemiplegia, which is rapidly disappearing.

Case 12.—Pte. T. M. B. Admitted thirty-six hours after infliction of wound.

On Admission.—Patient stuporous. Left hemiplegia present. The wound was lacerated and dirty, and contained numerous small metallic fragments.

Operation.—Excision of wound, removal *en bloc* of depressed fracture. Four bone fragments were driven deeply into the cortex. When replaced, these reconstituted the mosaic of inner table (*Fig.* 83). The wound was sutured over a B.I.P.P. pack, and healed without incident (*Fig.* 84).

FIG. 83.—*Case* 12. Mosaic of inner table. Fragments replaced.

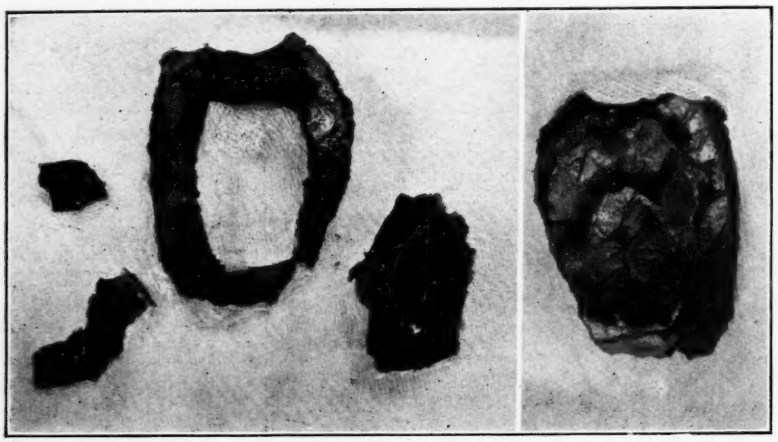
FIG. 84.—*Case* 12. Wound four weeks after operation.

Six weeks after the operation, voluntary motor power returned in the muscles of the thumb. The patient then rapidly regained movement in both upper and lower limbs, and three months after the operation was able to walk.

The next case illustrates an occipital lesion with hemianopsia.

Case 13.—Pte. A. G. F. Admitted twenty-four hours after injury.

On Admission.—Patient stuporous. No other abnormal signs on neurological examination before operation. *X*-ray plate showed three fragments driven into occipital lobe.



A. *B.*

FIG. 85.—*Case* 13. *A.* Outer table and fragments. *B.* Inner table reconstituted.

Operation.—Excision of wound. Removal of fracture *en bloc.* Three bone fragments removed from brain. When placed in position these accurately restore the continuity of the bone (*Fig.* 85). The wound was sutured with glove-rubber drain and healed by first intention.

The patient would answer questions two days after the operation, when a left hemianopsia with contraction of the right fields was demonstrated. Accurate investigation was impossible at this stage. Six weeks later a quadrant defect remained (*Fig.* 86).

Cerebellar and temporal lesions have, it is stated, a better prognosis than is the case with wounds nearer the vertex. This is probably due to the fact that in these cases the cerebral wounds are well covered by a muscular layer, and their reinfection from the skin is not so frequent.

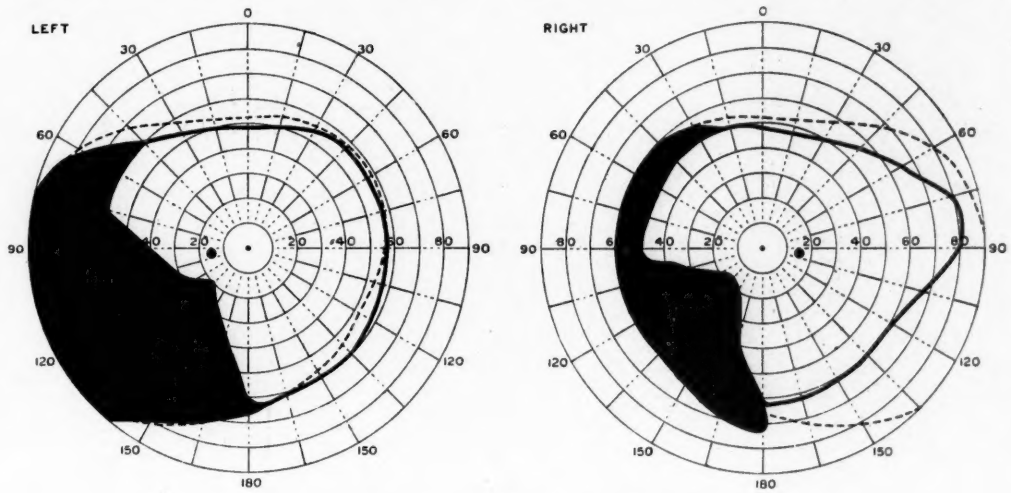


FIG. 86.—*Case* 13. Visual field six weeks after operation.

Case 14.—Pte. W. E. G. Operation six hours after infliction of wound.

On Admission.—Patient stuporous. Glancing wound of left cerebellar region.

Operation.—Wound excised. Fracture of occipital bone immediately lateral to torcular Herophili exposed. The fracture was removed *en bloc*. There was no sinus injury, but a wound in the dura, 1 inch in length, over the cerebellum. Several small fragments were removed from the cortex. After irrigation, the dura was sutured with fine catgut. The muscles and skin were then sutured with glove-rubber drainage.

Healing by first intention.

Progress report four months later: No abnormal signs.

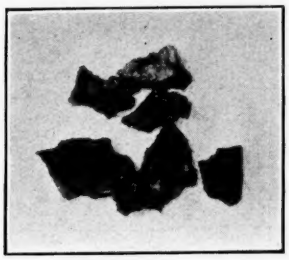


FIG. 87.—*Case* 15. Fragments removed from temporal lobe.

FIG. 88.—*Case* 15. Wound fourteen days after operation.

Case 15.—Pte. H. B. Temporal lesion. Admitted two days after injury.

On Admission.—Patient states that he was unconscious for about one hour, and can remember walking to the dressing station. Lacerated wound in left temporal region, with small hernia cerebri.

Operation.—Wound excised by curved incision. Burr opening at edge of fracture, which was then enlarged by a rongeur, so that the wound in the dura was completely exposed. Numerous fragments were removed from left temporal lobe (*Fig.* 87).

The wound was sutured without drainage, and healed well (*Fig.* 88).

In the following case there was a large bone defect in the right frontal region, extending almost to the supra-orbital margin, from which fissures radiated in various directions.

Case 16.—Sgt. W. P. Admitted three days after injury.

On Admission.—Large wound in right frontal region, with offensive hernia cerebri. Patient was extremely restless and irrational. General condition poor. Temperature 103°; pulse-rate 120. *X*-ray report: Fracture, with fissuring in frontal bone (*Fig.* 89).

Operation.—Patient was so restless that a general anæsthetic was administered. Wound excised by curved incision. Burr opening at margin of fracture, which was then enlarged to expose

FIG. 89.—*Case* 16. Large defect in frontal bone, with fissuring.

the dural edge. There was a very extensive laceration of the right frontal lobe, without many ndriven fragments. Wound sutured over a B.I.P.P. pack.

Bacteriological Report.—Anaerobic bacilli; short-chain streptococci and staphylococci.

No hernia cerebri occurred, but there was some superficial infection of the wound, one part of which healed by granulation. Two months after the operation, mental condition was not quite normal, but had improved considerably.

Fatal Cases.—In the first of these cases a piece of wire had been driven some distance under the scalp from the wound. This track was not completely excised, and was responsible for a rapidly-spreading infection.

Case 17.—Pte. C. Y. Operation was performed ten hours after infliction of wound.

On Admission.—Gutter wound of right temporal region, with several metallic fragments in the wound. *X*-ray showed tangential fracture of squamous temporal region, with fissuring extending to the base of the skull.

Operation.—Wound excised. Piece of wire 2 inches long embedded in scalp. This wound was partly excised, the remainder being curetted and treated with B.I.P.P. The fracture was enlarged by a rongeur to expose the dural edge. The wound in the brain was irrigated after removal of loose fragments of bone. Sutured, with glove-rubber drain. Infection spread from site whence the wire had been removed, and involved the whole wound. A soft fungus rapidly developed, and the patient died five days after the operation.

Autopsy.—No bone fragments were found in the brain. Infection apparently spread from the superficial part of the wound.

In the next case death was due to an incomplete removal of bone fragments, which were small and scattered. This case was operated upon before it was realized that it was necessary to spend a considerable time in the search for these fragments.

Case 18.—Pte. L. C. Operation performed thirty-six hours after the infliction of the wound.

On Admission.—Patient stuporous and restless. Large ragged wound in the right temporal region. *X*-ray report states: Tangential fracture, with numerous indriven fragments.

Operation.—Removal of fracture *en bloc* (*Fig.* 90). Small fragments and a large blood-clot removed from temporal lobe; wound sutured, with glove-rubber drain. The general condition was improved on the following day, but subsequently a hernia cerebri appeared, the patient had many convulsive attacks, and death occurred on the sixth day.

Autopsy.—Large disintegrated area in the right frontal lobe, in which there were severa unremoved fragments. (Brain preserved for examination.)

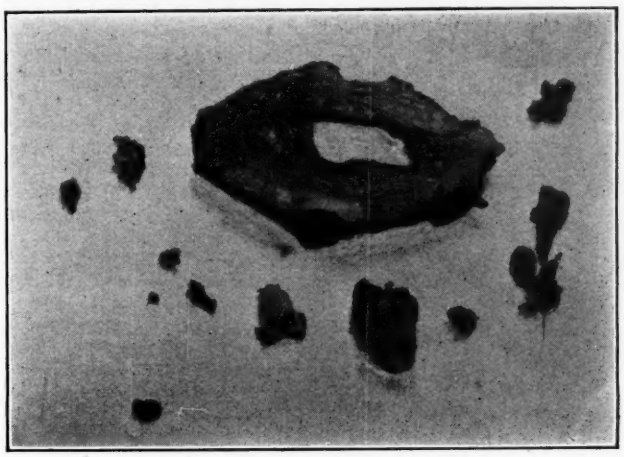


FIG. 90.—*Case* 18. Fracture of bone fragments. Incomplete removal demonstrated at autopsy.

The following case illustrates the third factor, namely, the influence on the result of delay in operating.

Case 19.—Pte. B. This case was not admitted until the fifth day after the injury. The wound was in the right post-parietal region and was grossly infected. The temperature was 104° on admission; pulse-rate 130. The usual operation was done, but the infection spread, and the patient died thirty-six hours later. There was no autopsy.

The following conclusions are to be drawn from these fatal cases: (1) Excise the wound completely; (2) Remove all indriven fragments; (3) Operate as early as possible after the infliction of the wound.

Group III.—WOUNDS OF PENETRATING TYPE WITH LODGEMENT OF PROJECTILE AND BONE FRAGMENTS.

In this group of injuries there is typically more destruction of cerebral tissue than in *Group II.* In the latter group the whole force of the impact is not directed into the brain. This is demonstrated in the accompanying diagram (*Fig.* 91). In *Group III* the

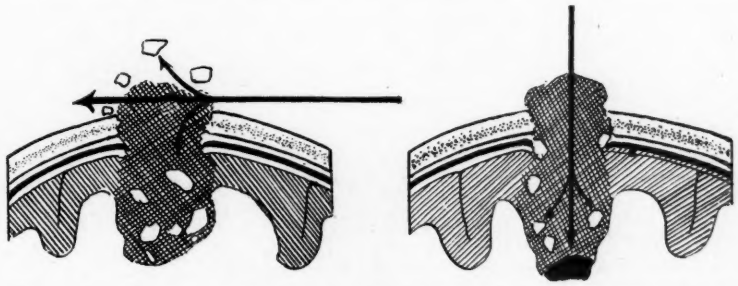


FIG. 91.—Diagram to illustrate type of injury and direction of force in *Groups II* and *III.*

technical difficulties are further increased by the problem of removal of the projectile. It must be emphasized that the more severe types of tangential injury may cause greater

cerebral laceration than is present in certain cases in this group, and that the prognosis is largely dependent upon the extent of the laceration.

In the following case the projectile was easily accessible, and was removed.

FIG. 92.—*Case* 20. Diagram of injury.

Case 20.—Sgt. D. Admitted two days after injury. Irregular wound, with brain tissue exuding in the right frontal region.

On Admission.—Patient unconscious. No localizing neurological signs. *X*-ray showed fracture of frontal bone on the right side. Two metallic fragments in the frontal lobe (*Fig.* 92).

Operation.—Wound excised by tripod incision. Fracture removed *en bloc*. Bone fragments and projectile removed from the brain. B.I.P.P. pack, wound sutured. Pack left *in situ* for three days. The wound healed well (*Fig.* 93).

Patient regained consciousness on the day following the operation, and became very restless and excitable for some four days afterwards. Two months later there were no complications and the man's mental condition was normal. It is of interest to note that in this case and in *Case* 16, where the injury was in the right frontal region, the mental disturbance was much more marked than in *Case* 11, where there was a left frontal-lobe injury.

In the next case no attempt was made to remove the projectiles, which were deeply situated in the middle fossa.

Case 21.—Rfm. C. Operation twelve hours after the infliction of the wound.

On Admission.—Patient unconscious. Left hemiplegia present. Entrance wound in the right frontal region. *X*-ray plate shows several metallic fragments lying lateral to the pituitary fossa on the right side.

Operation.—The wound was excised, and disorganized brain and bone fragments were removed. Wound drained by a paraffin-gauze strip.

One month after the operation the wound had healed. The patient would answer questions rather stupidly. Voluntary movement had returned at the hip- and knee-joints, but not at the ankle-joint or in the upper limb.

FIG. 93.—*Case* 20. Wound four weeks after operation.

In the next case the projectile had lodged in the wound and had driven the bone fragments deeply into the brain Though there was no intracerebral projectile, the character of the injury warrants its inclusion in this class. This case was also of interest in that a 'sinus syndrome' was present, despite the fact that no gross lesion of the sinus was demonstrated.

Case 22.—Pte. D. H. Admitted thirty-six hours after wound.

On Admission.—Conscious, answers questions, but resents interference. Large lacerated wound in the parietal region extending across the mid-line. Fracture of the right parietal bone. *X*-ray report states: deep indriving of fragments. No voluntary power in lower limbs; weakness of right upper limb. Deep reflexes increased in these limbs. Superficial reflexes not elicited. Double extensor plantar response.

Operation.—Excision of wound. Removal of fracture *en bloc*. Fragments removed from

the brain. There was no obvious sinus injury, and the dural wound was completely on the right side of the mid-line. The wound was treated with B.I.P.P. and sutured. A small hernia developed ten days after operation, but subsided in three weeks, when the wound rapidly epithelialized.

A subsequent *x*-ray examination revealed the presence of a small bone fragment, which was doubtless responsible for the delay in healing. As the patient continued to improve, the fragment was not removed.

Three months after the operation, range of movement was normal in the right upper limb, though the power was less than in the left upper limb. Spasticity of both lower limbs was pronounced, but voluntary movement through almost normal range had returned at both hip- and knee-joints. No movement was present in the muscles of legs or feet. The deep reflexes were exaggerated, and R and L patella- and ankle-clonus were present. There was no sense of muscle position at the ankle- or toe-joints, but movement at the hip- and knee-joints was correctly perceived. Localization of touch was not accurate. The mental condition was normal.

The next case demonstrates the immediate recovery possible in apparently hopeless cases. There were two penetrating wounds in the left parietal region and a depressed fracture of the frontal bone. The bacteriological infection was most formidable.

Case 23.—Pte. H. Admitted two days after infliction of wound.

On Admission.—Two penetrating wounds in the left parietal region; small glancing wound in the right frontal region. *X*-ray report says: two small metallic fragments at the base of the brain on the left side.

Operation.—Wounds and fractures in the parietal region excised. Small bone fragments removed from the brain. Wound irrigated. Sutured over a B.I.P.P. pack. Wound of frontal region excised. Depressed fracture removed *en bloc*; no dural penetration. Wound sutured.

Bacteriological Report (culture from indriven fragment).—Anaerobic bacilli, type *B. Welchii*. Streptococci, long-chain type; staphylococci; micrococci, type tetragenus. Bacilli, other types.

The wounds healed with only one area of superficial suppuration. Fourteen days after the operation the patient, who had been very noisy, became quieter, and would answer questions rationally. One week later, in response to requests from relatives, he was evacuated to England, as a further improvement had taken place in his mental state.

Fatal Cases.—These cases may be divided into two groups: (1) Patients comatose on admission, who died shortly afterwards without regaining consciousness. The condition

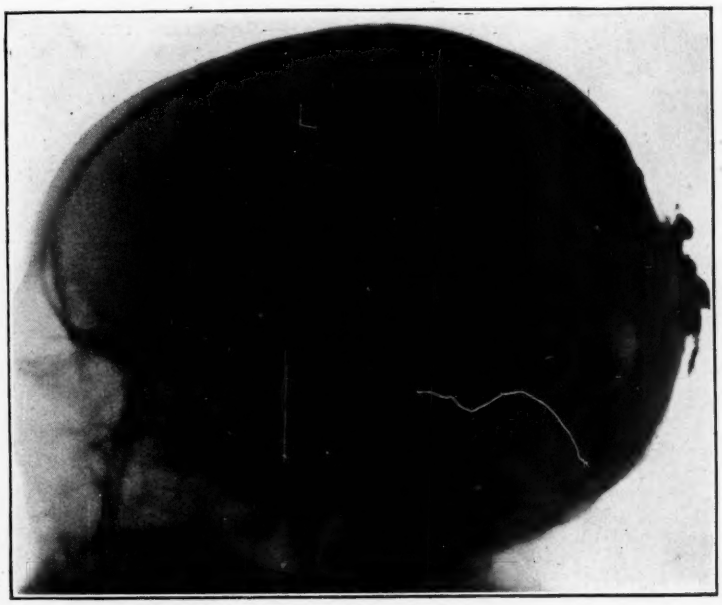


FIG. 94.—*Case* 25. Numerous intracranial projectiles.

of these patients did not admit of serious surgical treatment. (2) Patients in whom infection of the wound was present, and who died from cerebritis at a variable period after the operation.

Of the 6 fatal cases, 3 are included in each group. Two cases will be quoted. In the first, recovery would have followed earlier operative intervention; whilst in the second, the multiplicity of the foreign bodies and the extent of the cerebral injury rendered effective operative treatment very difficult.

Case 24.—Pte. J. B. This man had been lying in a shell-hole in 'no-man's land' for two days, and on admission was very exhausted. There was a small, very infected wound of the left parietal region.

X-ray Report.—Fracture of left parietal bone. Metallic fragment 1 inch from surface.

Operation.—Wound and fracture excised. Gas gangrene was present in the brain. The projectile was removed and the wound cleaned, but a cerebral hernia developed, and the patient died two days after the operation.

Case 25.—L.-Cpl. S. S. Admitted thirty-six hours after injury.

On Admission.—Large wound in occipital region containing numerous pieces of metal. Patient stuporous.

X-ray Report.—A large number of fragments of metal passing forwards superficially in the right occipital cortex (*Fig.* 94).

Operation.—The fragments were not completely removed, and the patient died of acute cerebritis two days later.

Group IV.—WOUNDS INVOLVING PENETRATION OF THE VENTRICLES.

There have been no certified recoveries in any case of this type. Cushing has had a similar experience. One case survived for the extraordinarily long period of fourteen days; another lived for seven days; but the remainder all died soon after admission.

FIG. 95.—*Case* 26. Diagram of course of projectile.

Case 26.—Sgt. D. Admitted eight hours after infliction of wound.

On Admission.—Comatose. Babinski reflex elicited on both sides. Superficial abdominal reflexes absent. Small wound of entry above left ear. *X*-ray showed a projectile in right frontal lobe (*Fig.* 95).

Operation. — Decompression at site of entrance wound. Some bone fragments removed from track. Death twenty hours after operation.

Autopsy.—The projectile, a piece of high-explosive shell, had traversed the body of the left lateral ventricle and the anterior horn of the right lateral ventricle. There was considerable hæmorrhage along the track, and ventricular sepsis had occurred.

Case 27.—Pte. R. M. Admitted two days after wound.

On Admission. — Unconscious. Small entrance wound above left ear. Considerable laceration of the pinna. *X*-ray shows foreign body near the mid-line in the left frontal lobe.

Operation.—Decompression at the site of entrance. Projectile not removed. The patient remained unconscious for five days.

Autopsy.—There was a considerable meningeal infection around the cortical wound. (Brain preserved for investigation.)

FIG. 96.—*Case* 28. Fracture of vertex. Projectile at base of skull.

Case 28.—Pte. W. G. M. Admitted six days after injury. Casualty clearing station notes: "Compound fracture of skull, with hernia cerebri. Right hemiplegia. Comatose. Evacuated to the base."

On Admission.— Large lacerated wound in mid-line, brain tissue exuding. *X*-ray shows fracture of vertex, metallic fragment at base of brain (*Fig.* 96).

Operation. — Cleansing of track after removal of wound and fracture *en bloc*. Glove-rubber drain. A cerebral hernia (*Fig.* 97) developed after the operation, but the patient lived for eight days.

Bacteriological Report.—Anaerobic bacilli, long-chain streptococci, and staphylococci.

Autopsy. — The projectile had penetrated the third ventricle, and there was an intense infection of the meninges, the cerebral tissues, and the ventricular system.

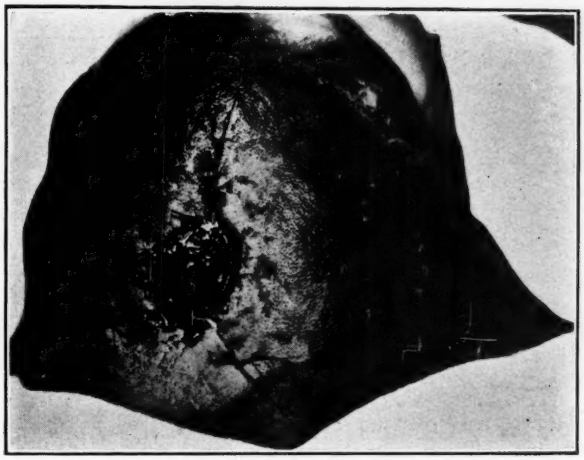


FIG. 97.—*Case* 28. Cerebral hernia after operation.

Group V.—WOUNDS INVOLVING BOTH THE BRAIN AND AN AIR SINUS.

In this type of injury the difficulties of treatment are increased by the risks of infection from the air sinus. Of the four cases of this group the frontal sinus was involved in two, whilst in the remaining cases the ethmoidal air-cells were fractured by the projectile. In the frontal-sinus cases the cerebral injury was not extensive, and both patients recovered. The ethmoidal cases, on the other hand, died of cerebromeningitis.

Frontal Sinus Injury.—The following case will serve as an example:—

Case 29.—Pte. J. L. Admitted six hours after injury.

On Admission.—Vertical wound in the right supra-orbital region. Mental condition normal; no abnormal signs on neurological examination.

Operation.—The wound was excised and the fracture exposed. It involved the anterior wall of the frontal sinus. A burr opening was made above the sinus and the dura exposed. The anterior sinus wall was removed, thus revealing a projectile embedded in the posterior sinus wall and projecting into the dura; it was removed, together with some bone fragments. The dural wound, ½ inch long, was sutured, and the scalp wound closed with rubber-glove drainage. It healed uneventfully, and the patient was evacuated to the base quite well three weeks later.

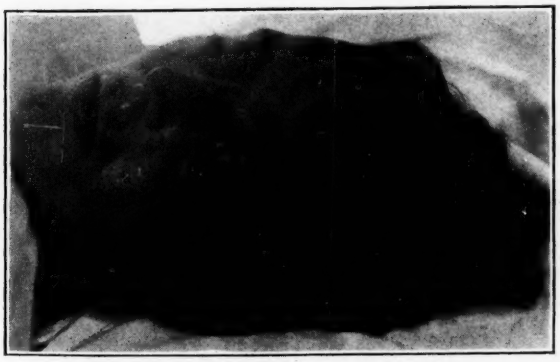


FIG. 98.—*Case* 30. Wound of entrance. Exophthalmos.

Suture of the dura is indicated in this type of case, as thereby the risk of cerebral infection is diminished. Owing to an early operation it was fortunately possible in this case.

Ethmoidal Cases.—In the first case of this type the projectile had traversed the orbital cavity, causing an arterio-venous aneurysm of the ophthalmic vessels and a pulsating exophthalmos; then, passing through the lateral mass of the ethmoid bone, it had lodged in the opposite frontal lobe, whence it was removed. Death from meningitis occurred seven days after the operation.

Case 30.—Pte. G. W. Admitted four days after the infliction of the wound.

On Admission.—The patient was conscious, and there were no localizing neurological sign

The wound of entrance was just above the left zygoma ; there was a pulsating exophthalmos of the left eye (*Fig.* 98). *X*-ray showed fractures of the lateral wall of the orbit, the lateral mass of the ethmoid, and the cribriform plate ; the projectile had lodged in the right frontal lobe (*Fig.* 99).

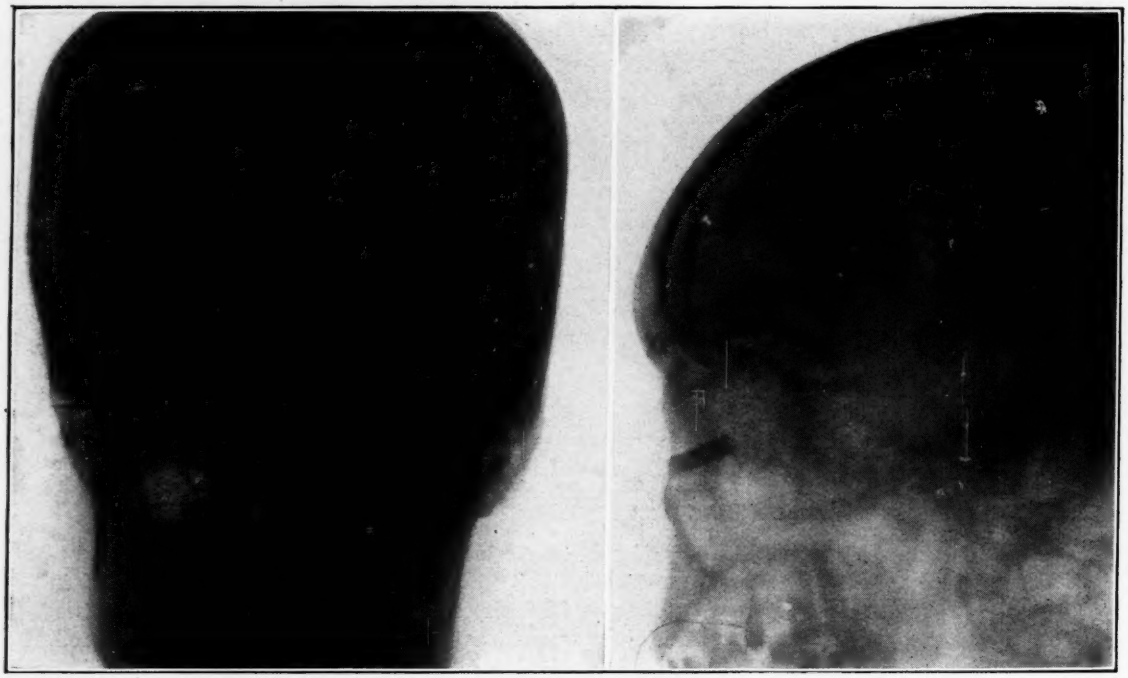


FIG. 99.—*Case* 30. Antero-posterior and lateral views of projectile.

Operation.—This was performed in two stages. First stage : General anæsthesia. Left common carotid artery exposed and temporarily controlled. Left eye enucleated. Strong pulsation palpable in the orbital cavity. Wound of entrance excised and outer wall of orbit removed. The projectile had passed through the middle of the cavity. A hæmostatic forceps was applied to the tissues at the apex of the orbit, and the contents of the orbital cavity were freely removed. A flavine pack was placed in the orbital cavity. The common carotid artery was not tied, and the wound in the neck was sutured. Second stage : Two days later the pack was removed and the forceps released ; there was no hæmorrhage. The projectile was then localized by the apparatus devised by Captain Ferguson[7]. Under local anæsthesia the right frontal cortex was exposed, and the projectile, an irregular piece of high explosive (*Fig.* 100), was removed. The temperature, which was 101·5° on admission, remained high. The patient became steadily weaker, and died five days after the operation.

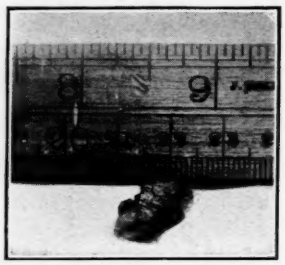


FIG. 100.—Projectile removed in *Case* 30.

Autopsy.—There was an extensive basal meningitis, which was most marked in the ethmoidal region, where the air-cells communicated with the meninges. The wound in the cortex through which the projectile had been removed was clean. The cavernous sinus was not injured ; the vascular lesion had been entirely intra-orbital.

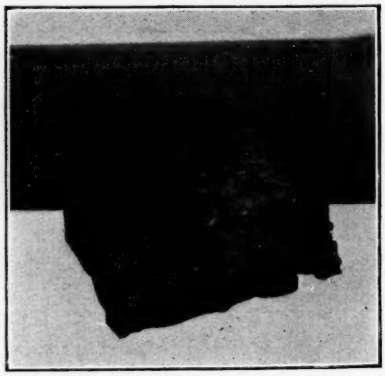


FIG. 101.—*Case* 31. Weight of projectile 121½ grms.

The next case is of interest owing to the size of the projectile, which weighed 121½ grms.

Case 31.—Pte. B. Admission twelve hours after injury.

On Admission.—There was a large entrance wound in the right temporal fossa. Marked proptosis of the right eye was present. The patient was stuporous.

Operation.—The wound was excised and a fracture of the temporal bone removed. The projectile (*Fig.* 101) had lacerated the apex of the temporal lobe, penetrated the orbit, and had lodged in the inner part of this cavity, penetrating the ethmoidal air-cells. It was removed, and the wound cleansed after enucleation of the eye. Drainage through the orbit. The patient improved for two days after the operation, but then signs of infection manifested themselves, and death from meningitis occurred on the sixth day.

Group VI.—THROUGH-AND-THROUGH CRANIOCEREBRAL WOUNDS.

Wounds of this type, as seen in hospital, have a more favourable immediate prognosis than is the case with lodging wounds. This may be attributed to the fact that, as a general rule, only the more superficial types of through-and-through wounds survive to reach a hospital. In these cases, further, the track can be easily cleaned, and efficient drainage is provided by the nature of the wound.

There were six cases of this type in this series. Of these, only one died in hospital. Suppuration was present in two cases when they were evacuated, and unfortunately no subsequent reports have been received from these. The end-result is therefore in doubt.

FIG. 102.—*Case* 33. Exit wound in cerebellar region.

Case 32.—Pte. C. G. H. Admitted three days after injury.

On Admission.—Small entrance wound above and behind left ear. Larger exit wound above and to the left of external occipital protuberance. The patient would answer his name, but was unable to give particulars or to frame any coherent sentence. He was very irritable. *X*-ray showed small indriven fragments at entrance wound. Explosive fracture at exit.

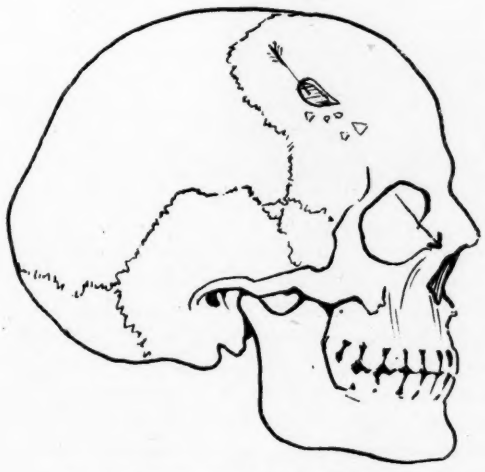


FIG. 103.—Illustrating fronto-orbital wound.

Operation.—Both wounds excised. Indriven bone removed from entrance wound. Exit wound cleaned. Suture, with glove-rubber drainage. Infection occurred at wound of entrance, which eventually healed without the formation of a hernia.

There was no interference with visual acuity or the visual fields, doubtless due to the fact that the wound involved only the outer surface of the occipital lobe. The aphasia soon subsided, and three weeks after the operation the patient's mental state was quite normal.

A striking illustration of the importance of complete removal of indriven fragments is

afforded by these cases of through-and-through wounds. The actual cerebral laceration is frequently greater at the exit wound. But here bone fragments are absent, and healing occurs with much greater facility than is the case at the wound of entry.

Case 33.—Pte. C. In this case there was a very marked explosive wound in the cerebellar region just to the left of the mid-line (*Fig.* 102).

This wound was excised, and, despite the extensive cerebellar injury, healed without difficulty The entrance wound in this case was small, and there was only one indriven fragment, situated at the lateral border of the left lobe of the cerebellum.

In two cases the wound involved the frontal lobe and the orbit (*Fig.* 103). This type is more difficult; reinfection through the orbit is difficult to prevent. Both cases became infected after some days, and in one of these a hernia developed at the entrance wound; both were evacuated after six weeks, somewhat improved but still suppurating. These cases, therefore, cannot be regarded as successful. The operative technique employed was the usual cleansing of the entrance wound and removal of bone fragments, with removal of the eye and drainage through the orbit.

Group VII.—WOUNDS INVOLVING INJURY OF A VENOUS SINUS.

The operative technique has been improved by the adoption of the muscle-graft method of arresting hæmorrhage, which was first introduced by the late Sir Victor Horsley, and which was certainly not the least of the contributions made by him to surgical knowledge. Hæmorrhage is more easily arrested by a muscle graft; but a graft from the epicranial aponeurosis is more easy to obtain and is almost as efficient in its action.

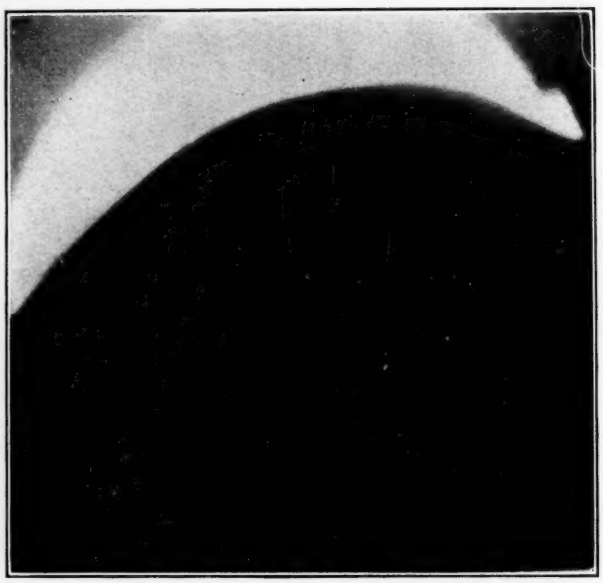


FIG. 104.—*Case* 34. Depressed fracture indicated by arrow.

Attention has already been directed to the importance of an *en bloc* removal of the fracture in cases where a sinus injury is suspected. In this series there were four cases of sinus injury, with no deaths. In no case was the sinus completely divided, and all were treated by the muscle or fascial method. In three cases the longitudinal sinus was involved; in the remaining case there was a small tear in the lateral sinus.

Case 34.—Pte. J. S. Admitted two days after injury.

On Admission.—Large scalp wound passing transversely across the vertex in the post-parietal region. No abnormal signs on neurological examination. *X*-ray showed a depressed fracture (*Fig.* 104).

Operation.—Fracture removed *en bloc* (*Fig.* 105). The fragments of inner table had lacerated the longitudinal sinus, and free hæmorrhage occurred on removing the fracture. This was successfully controlled by a graft from the epicranial aponeurosis. The wound was then sutured, without drainage. It healed uneventfully (*Fig.* 106).

FIG. 105.—*Case* 34. Depressed fracture of inner table.

FIG. 106.—*Case* 34. Wound three weeks after operation.

The following case illustrates an injury of the lateral sinus. The wound was small, and the hæmorrhage was easily controlled by a muscle graft.

Case 35.—Pte. E. W. Admitted six hours after injury.

On Admission.—There was a large lacerated wound in the occipital region extending across the mid-line.

Operation.—The wound was excised and a depressed fracture of the occipital bone removed. One fragment had penetrated the left lateral sinus 1 cm. to the left of the torcula. It was removed, and a graft from the complexus muscle applied. There was also a superficial laceration of the cerebellum. This was irrigated and the dural wound sutured. The wound was sutured, with a glove-drain *in situ*. The drain was removed on the second day. The wound healed by first intention.

In a subsequent report two months later the patient stated that he was quite well.

Of the two remaining cases of injury to the longitudinal sinus, the wound in the first was small and was situated in the frontal region ; whilst in the second case it was 2 cm. ventral to the torcula. Neither in this latter case nor in *Case* 34 was 'a sinus syndrome' observed.

This syndrome was described by Holmes and Sargent.[11] It is characterized by a paresis of unusual distribution, affecting the lower, and frequently the upper, limbs in various combinations. This paresis is more marked in the proximal segments in the upper limbs and the distal segments in the lower limbs ; the paresis is accompanied by a striking degree of rigidity. Sensory disturbances of a cortical type are usually present. There is an absence of shock to the lower centres, which reflexly maintain tone. The peculiar distribution of the paresis is explained by the arrangement of the cortical motor centres and the cortical veins. The symptoms are attributed by the authors to the venous lesions present. As this syndrome has been usually observed in lesions over the motor cortex, and has not been observed in sinus lesions posterior to this area, it is generally held that the factor of direct concussion to the cortex must play an important part in the etiology.

CONCLUSIONS.

1. Operation should be performed at the earliest possible moment after the infliction of the wound.

2. Local anæsthesia should be employed.

3. The wound should be completely excised, the fracture removed *en bloc*, and the brain wound cleaned gently and thoroughly by the catheter method.

4. In the infected wounds the B.I.P.P. pack method is of great service.

5. The prognosis depends largely upon the extent of the cerebral injury.

6. The real gravity of cerebral wounds can only be judged by statistics extending over long periods. The results will be influenced by two factors: (*a*) The extent of the cerebral lesion; and (*b*) The completeness of the operation.

7. A careful, gentle, and thorough cleansing of the cerebral wound will reward the surgeon a thousandfold for the time spent in its accomplishment.

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[7] Ferguson, *Brit. Jour. Surg.*, 1919, vi, 409.
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[9] Marie, quoted by Willems (*v. supra*).
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CONTUSION OF ARTERIES.

By Major WILLIAM ANDERSON, O.B.E., R.A.M.C.

In the literature of the surgery of the war, small reference has been made to this type of injury. As a probable cause of secondary hæmorrhage or aneurysm it is of considerable importance and interest.

The subject is discussed in one of the Military Medical Manuals—*Wounds of Vessels*, by Professor Sencert,—but except for the report of a case by Lieut.-Colonel J. F. Dobson and Captain W. R. Higgins in the British Journal of Surgery, July, 1918, I cannot find any other reference to it. The literature at my disposal, however, is limited.

It may be of interest to report the following ten cases which I have treated at casualty clearing stations. All were seen within twelve hours of being hit. In many more I suspected the condition; but, owing to the impossibility of retaining the cases, I was compelled to evacuate them and merely note the probability of its existence on the field medical card.

It was not until the early part of 1917, when I saw cases of "vein divided and artery intact" operated on which later developed "severe secondary hæmorrhage," that I began to suspect a primary, although not obvious, injury to the artery. On investigating the next case of this type of injury which came under my care, I found that the wall of the artery was bruised, and that the pulsation distal to this was a 'transmitted' one. Suspecting the presence of a thrombus, I deliberately opened the vessel after clamping, and found the condition so well described and illustrated by Lieut.-Colonel Dobson and Captain Higgins, namely, rupture of the internal and middle coats of the vessel for about two-thirds of its circumference, and only the smallest amount of clot at the edges of the curled-up coats.

All the subsequent cases presented the same pathological appearance. They were all seen while on 'team' duty during active fighting, and my notes are not so full as might be desired. I append a table giving the more important points where they have been noted.

Mechanism of Production. — Sencert suggests three possible causes of arterial contusion: (1) Direct shock; (2) Indirect shock; (3) Overstretching of the vessel.

In two of my cases, Nos. 2 and 4, the outer sheath enclosing the artery and vein was not penetrated, but showed slight bruising. The injury of the artery was found after opening up this sheath. In considering the mechanism of production the following points seem to be of interest:—

1. The velocity of the missile. All the cases except No. 1 were entrance and exit wounds.
2. In all the cases the artery lay between the track of the missile and a bone.
3. The injury of the vessel was always on the side next the track.

Pathological Anatomy.—Sencert describes three degrees of this condition: (1) Where the internal coat only is affected, showing fine striated lines; (2) Where these lines penetrate into the middle coat; (3) Where the internal and middle coats are ruptured circularly around the entire circumference of the vessel. All my cases fall into the second group.

The external appearance was characteristic, showing bruising of the vessel wall and a slight bulging towards the track of the missile (*Fig.* 107). In some cases there was distinct but diminished 'expansile' pulsation *below* the site of injury. In three cases I opened the artery at the primary operation, and found only shreds of blood-clot in the vicinity of the torn coats. In the others, which were opened five to eight days after injury, there was a

PARTICULARS OF TEN CASES OF CONTUSED ARTERIES.

	Artery	Gross Injury to Vein	Anæmia of Patient	Distal Pulse Present	Early Treatment	Missile	Nature of Wound	Result	Remarks
1	Common femoral	Yes	Marked ..	Yes, diminished	Artery explored and sutured	Shell fragment	Lodged in gluteal region	Gangrene	High amputation on 3rd day; patient died.
2	Superficial femoral	No	Marked ..	Not noted	Artery explored and sutured	Bomb fragment	Entrance and exit	Gangrene	Amputation on 3rd day. Posterior tibial pulse felt faintly for 18 hours after the operation. Concomitant injury to deep femoral. Multiple wounds, including penetrating wound of skull. Patient died on 3rd day.
3	Superficial femoral	Yes	Slight ..	Yes, diminished	Vein tied ..	Bullet ..	Entrance small, exit large	Recovery	Ligation on 3rd day; vessel thrombosed; collateral circulation good.
4	Axillary ..	No	No ..	Not noted	Artery explored and sutured	Bullet ..	Small entrance and exit	Recovery	Ligation on 4th day; radial pulsation felt for 2 days after operation; vessel completely occluded when tied.
5	Brachial ..	Yes	No ..	Very feeble	Veins tied ..	Bullet ..	Entrance and exit	Recovery	Ligation on 5th day; vessel occluded
6	Brachial ..	Yes	Yes ..	No ..	Veins tied ..	Shell fragment	Large gutter	Recovery	Ligation on 5th day; vessel occluded.
7	Popliteal	Yes	Slight ..	Diminished	Vein tied ..	Bullet ..	Entrance and exit small	Recovery	Ligation on 5th day; vessel occluded.
8	Posterior tibial	Yes	No ..	Present ..	Veins tied ..	Shell fragment	Entrance and exit, with fracture of fibula	Recovery	Ligation on 6th day; pulse behind internal malleolus still present; injury to vessel slight.
9	Ulnar ..	Yes	No ..	?	Veins tied ..	Bullet ..	Entrance and exit, with fracture of ulna and divided ulnar nerve	Recovery	Ligation on 3rd day; vessel was freely exposed by missile, and was, I think, occluded at time of primary operation.
10	Ulnar ..	No	No ..	Not noted	Wound cleansed	Shell fragment	Entrance and exit; fractured ulna	Recovery	Ligation on 3rd day; vessel occluded.

firm clot extending for a varying distance above and below the injury, and completely occluding the vessel. When this was washed off, the appearance of the artery was identical with the first three cases, namely, a rough thinned-out irregular area on the side next the wound track made up of tunica adventitia only, and bounded by the curled-up edges of the tunicæ media and intima (*Fig.* 108). This area occupied from a half to two-thirds of the circumference of the vessel, and in length varied from a quarter to three-quarters of an inch, depending on the size of the vessel. The rest of the artery appeared normal.

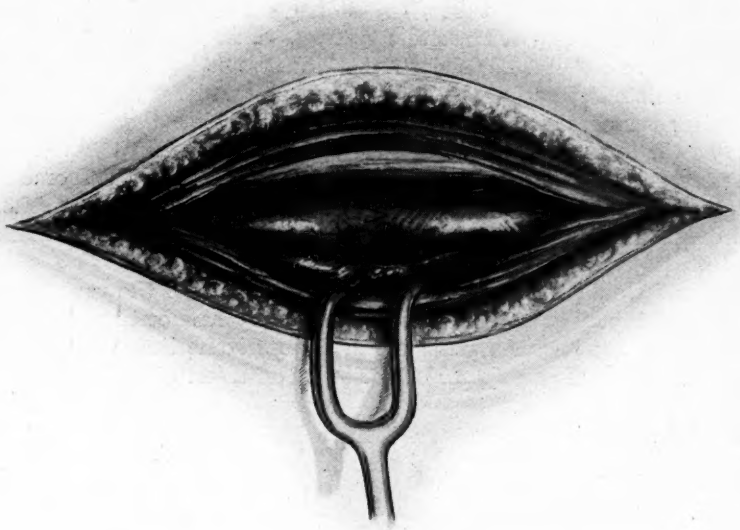


Fig. 107.—External appearance of injured vessel, showing bruising and bulging of the wall.

It would be of interest to know the condition of the accompanying vein when not penetrated, but I have not had an opportunity to investigate this.

Diagnosis.—Some of the cases of contusion of an artery can be diagnosed at once before such sequelæ as secondary hæmorrhage, traumatic aneurysm, dry gangrene, or embolism following thrombosis develop. The site of the wound, the diminution or absence of a distal pulse, and the appearance of bruising of the wall or sheath of the vessel, should arouse suspicion and call for a close examination. A peculiar 'hard' feeling of the muscles of the limb distal to the injury is found only when the lumen of the vessel is completely occluded. In a few of the cases there were well-marked local and general signs of hæmorrhage, but this was always due to penetration or division of the accompanying vein, or of a branch of the artery, and not to leakage from the vessel itself.

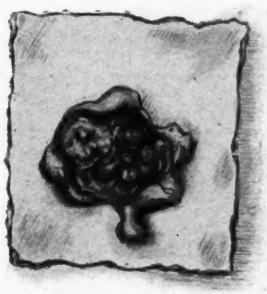


Fig. 108.—Internal appearance of injured vessel, showing exposed tunica adventitia and the curled up edges of tunicæ media and intima.

Treatment.—Very thorough opening up and cleaning of the wound is here, as in all blood-vessel injuries, a *sine qua non* to success. At first, as I expected to find only a thrombus, I opened the artery with the intention of removing the clot and re-establishing the circulation by suture of the vessel. Although I felt sure that the vessel would become occluded in a few days, I hoped that this would be gradual and allow for the establishment of collateral circulation, thereby diminishing the risk of ordinary gangrene or gas gangrene in the limb.

I gave up this procedure for the following reasons: (1) There is no clot at this stage. (2) It is impossible to suture or to trim satisfactorily the edges of the torn tunicæ. (3) Suture of the tunica adventitia alone is difficult and unsatisfactory. (4) One narrows the lumen of the vessel, and increases rather than lessens the chances of rapid clotting.

If there is even the faintest pulsation below the injury, it is better, I think, to leave well alone in all cases, and to tie the vessel above and below the injury on the fourth to the sixth day. On account of the great risk of gangrene where there is obviously no circulation through such arteries as the common femoral, popliteal, posterior tibial, or axillary, use should be made of Tuffier's tubes, or, as suggested by Sencert, of venous grafts, to re-establish the circulation, at least temporarily. I must confess that my experience of these methods of re-establishing the circulation has not been particularly happy; yet the results of immediate ligature are so bad as to justify their continued trial.

In the smaller vessels, primary ligation above and below the injury might be done, but I think it better to postpone this for four to six days—when delayed primary suture of the wound may be undertaken at the same time—in the hope that some blood may be getting through which will help to fight our persistent enemy, sepsis. After four to six days the risk of gangrene is much less, and secondary hæmorrhage is unlikely to occur before this date.

In conclusion, I would emphasize again the importance of the recognition and treatment of this type of injury as a preventive of secondary hæmorrhage, and would suggest that those traumatic arterial aneurysms which appear some little time after the man is wounded may in many cases owe their origin to a contusion of the arterial wall.

Since the above paper was written I have had the opportunity of seeing another case of this type of injury, which is of interest in that it occurred as the result of a motor accident, and not, as in the previous cases, of a gunshot wound. *Fig.* 109, explains the condition.

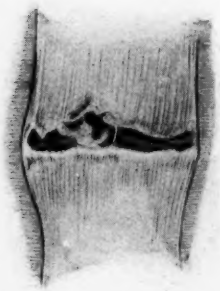


Fig. 109.—Opened posterior tibial artery, showing bulging above injury, circular tear of tunicæ media and intima, and small perforation of the exposed tunica adventitia.

The patient was injured as the result of a motor-car running into a tree. He was seated beside the driver, and was crushed between the seat and the dash-board. On admission he was collapsed and anæmic. There was a compound fracture of both bones of the lower third of the left leg, contusion of the left thigh and perineum, a superficial wound of the left upper arm, and dislocation of the left elbow (simple). After two and a half hours' resuscitation his general condition was improved, and, as he was oozing blood from the wounds, operation was undertaken.

The fractures of the leg bones were exposed and all lacerated muscles of the calf excised. The posterior tibial artery showed a point about the size of a pin's head from which blood spurted in jets. This was controlled by a single stitch, and the bleeding peroneal artery, which was deep in the wound, was ligated. The other wound was excised and the dislocation reduced. Three days later the foot was warm and movements were good. The posterior tibial artery was thrombosed for the whole length of the wound—about five inches—and was therefore ligated above and below. The tibia was plated and the wound closed. The patient, who is still in hospital, has done very well. The wound of the leg has healed by first intention except at one point where the strain on the stitches caused some cutting and sloughing of the skin edges. He has had difficulty in passing urine, and required the lodgement of a catheter for five days. I feared a rupture of the urethra, but there were no signs of extravasation, so I diagnosed bruising only. It was very difficult to control the fracture by external splinting alone, and plating gave very great relief to the patient.

I wish to express my thanks to Captains D. C. Norris and R. H. Urwick, R.A.M.C., for the drawings illustrating the naked-eye appearances.

THE ACTION OF CHEMICAL AND PHYSIOLOGICAL ANTISEPTICS IN A SEPTIC WOUND.

The Hunterian Lecture delivered before the Royal College of Surgeons of England on February 12, 1919.

By ALEXANDER FLEMING, London.

Since the war began, much attention has been directed to the treatment of suppurating wounds, for in the earlier years—1914–15–16—practically all the gunshot wounds became infected, and even in 1918 nearly all the wounds which were left open for more than a week became grossly infected with pyogenic cocci and other organisms.

Prior to the war, the surgeon gave most of his attention to aseptic methods, his great object being to exclude microbes from the wound. The question of how to deal with the bacteria after they were in possession was a problem of much less interest to him. I can remember in the days when I was first admitted to the surgical wards as a dresser, there were always a certain number of septic wounds which we were instructed to dress with this or that antiseptic, which stood in jars around the fire, and which we were told possessed great virtue as destroyers of microbes in the wound. These antiseptics were chiefly carbolic acid, mercury salts, and boric acid. The wounds were religiously dressed once or twice a day with these lotions, and although it was obvious that the antiseptic did not kill all the microbes in the wound, we were always told that it would kill many of them, and so the condition would be better than if no antiseptic were used. We were not then in a position to criticize this view.

At the beginning of the war in 1914, all the old antiseptics were used in military hospitals, in just such a manner as when I started surgery. Carbolic acid, perchloride or biniodide of mercury, boric acid, and hydrogen peroxide were poured into septic wounds once or twice a day, either singly or in mixtures of two or more, according to the fancy of the medical officer.

Very soon, however, campaigns were started in favour of particular antiseptics. Early in 1915, the merits of pure carbolic acid and of 2 per cent iodine in spirit were tested. A certain number of cases were treated with these two chemicals at the Front, and the patients were sent down to No. 13 General Hospital, where I had the opportunity of seeing the wounds and examining them bacteriologically. In the carbolic series there was a higher percentage of gas gangrene than in the general run of the wounded, while the iodine cases showed practically no difference from the cases treated in other ways. Soon after this, antiseptic pastes were advocated. The wound was plugged with the paste, but it soon appeared that in France, at any rate, the chief result of this method of treatment was to shut off all drainage, so that gas infections developed in a large number of cases. These pastes, therefore, very soon disappeared from the antiseptic armamentarium.

The first real advance in the 'antiseptic' treatment of wounds was the introduction of the hypochlorite solutions. Lorrain Smith introduced eusol, which is a solution of hypochlorous acid, while Dakin, about the same time, produced a solution of sodium hypochlorite, which has come to be recognized as Dakin's solution. Both of these solutions attained great favour in wound treatment, and I shall have more to say about their action later. About the same time that these solutions came into favour, new surgical procedures were introduced in the treatment of wounds, and thus the actual effects of the antiseptics were rather obscured. It was about this time that the importance of the thorough surgical cleansing of the wound was recognized, and that Carrel introduced his system of intermittent irrigation with the 'antiseptic' solution.

After 'Carrel' treatment came the era of B.I.P.P. This was a paste made by mixing iodoform, bismuth, and paraffin, and it obtained many supporters. It was, however, combined with very careful surgical treatment of the wound, and in connection with its use another factor was introduced into wound treatment, in that after treatment with the paste the wound was not touched for a considerable time, thus obtaining complete rest for the part and so aiding the physiological activities of the body in combating the infection. B.I.P.P. paste is not in itself an antiseptic, and Rutherford Morrison, who introduced it, has given directions for its sterilization before it is put into the wound. It was reported to have an antiseptic action when placed in contact with tissues or tissue fluids; but this we have never been able to demonstrate, and thus are forced to the conclusion that the paste is not a chemical antiseptic at all, but if it has any action in keeping down infection, it is due to some physical or physiological action.

After B.I.P.P. came the dye-stuffs. The antiseptic action of some of these dyes had been known for a number of years, and some of them had been used prior to the war, without much success, in the treatment of septic wounds. Churchman, Dreyer, and others had investigated the power of a number of the aniline dyes in inhibiting the growth of bacteria, and Browning recommended brilliant-green, and more especially flavine, to which he attributed very remarkable properties as an antiseptic for use in septic wounds. Flavine differed from the other antiseptics in that its bactericidal action was greater in a serous than in a watery medium. Browning maintained also that it killed all the common microbes found in wounds in a very high dilution, while it had little toxic effect on the tissues, as exemplified by leucocytes. I have already published my findings in connection with the antiseptic action of flavine. Briefly, I found that it had a very slight antiseptic action on some of the microbes found in wounds, such as *B. proteus* (which is one of the most common bacteria found in a septic wound). Its action on the pyogenic cocci was not nearly so marked as was maintained by the originators of the method, except where there was a minimal infection. In pus, also, it had little bactericidal action, and it had a very destructive effect on the leucocytes. Browning's findings that it had little action on the leucocyte, while it had a powerful bactericidal action, followed merely from the fact that he tesied the action on leucocytes for a few minutes only, whereas the action on the microbes was tested on a minimal infection for twenty-four hours. Flavine also has a remarkable affinity for the walls of the wound and for the dressing, so that it is rapidly picked up and rendered inert by these walls and by the gauze pack. Its great affinity for the dressing can be shown by the following simple experiment: A test tube is half filled with flavine 1–1000, and a tight-fitting cotton-wool plug is slowly pushed down into it, until fluid escapes above the plug. The first portion of fluid which comes through the plug will be found to be absolutely without the yellow colour of flavine, showing that the cotton-wool has been able to remove the whole of this substance from the solution.

It appears that flavine has the property of combining with and staining a large variety of substances, including bacteria. In a fluid, therefore, where the bacteria form the only stainable objects, the dye can exert its full strength on these; but in a wound or in pus, where the bacteria form only a very small part of the stainable material, the major portion of the dye is used up in staining the tissues and cells, and in this way the bacteria are largely protected from its action.

It was soon found in practice that when a wound was treated with flavine 1–1000 (the strength recommended) for more than a few days, all the reparative processes stopped, while the flavine did not sterilize the wound, so that for the continued treatment of septic wounds it was found quite unsuitable. In the later stages of the war it has been very largely used as a prophylactic, following the preliminary surgical cleansing of the wound. This use will be considered later, in dealing with antiseptics in primary and delayed primary suture.

There have been, during the war, two schools in the treatment of wounds: the *physiological school*, which concentrated their efforts in aiding the natural protective agencies of the body against infection, and the *antiseptic school*, which aimed at killing the microbes in the wound with some chemical agent.

PHYSIOLOGICAL TREATMENT.

Sir Almroth Wright and his followers have maintained that it is impossible for any of the commonly used antiseptics to have an appreciable effect in sterilizing a wound in which the infection has become established, and that the greatest benefit is to be obtained by aiding the physiological agencies which bring about the natural recovery from infection. Two such agencies especially have to be considered in connection with infected wounds : (1) *Blood and tissue fluids* ; (2) *Leucocytes.*

Blood and Tissue Fluids.—

Reaction.—The normal reaction of the blood fluids corresponds to a N/35 alkaline solution. The reaction of the discharges from a wound varies enormously, according to the microbes with which it is infected, and with their rate of growth.

Sir Almroth Wright has shown that some bacteria commonly found in wounds, e.g. *B. Welchii*, grow very badly in unaltered blood serum, but if the normal alkaline reaction is reduced or abolished, the bacilli will grow luxuriantly. *Fig.* 110 represents

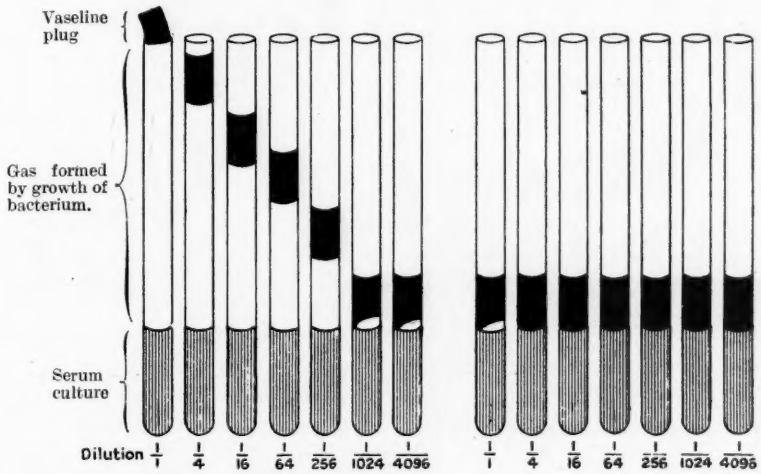

Vaseline plug
Gas formed by growth of bacterium.
Serum culture
Dilution 1/1 1/4 1/16 1/64 1/256 1/1024 1/4096
1/1 1/4 1/16 1/64 1/256 1/1024 1/4096
Serum from gangrene patient (alkalinity of serum = N/150).
Normal serum (alkalinity = N/35)

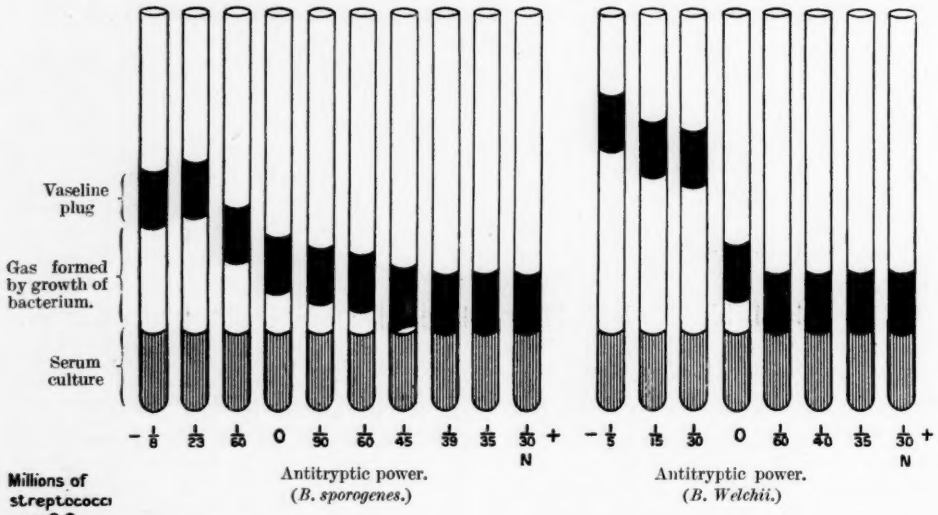
FIG. 110.—Growth of *B. perfringens* in twenty-four hours in serum from gangrene patient with acidosis.

the growth of *B. Welchii* in normal serum, and in serum from a patient with gas gangrene which had lost almost all its alkalinity. Into equal quantities of the serums graduated implantations of *B. Welchii* were made, and it will be seen that in the 'acidosed' serum from the gas-gangrene patient growth takes place with one-thousandth of the implantation necessary to induce growth in the normal serum. The gas-formation in the acidosed serum is also very much greater.

The alkalinity of the blood serum in toxic cases of gas gangrene has been found to be greatly reduced.[1] As an example, the serum used in the experiment illustrated in *Fig.* 110 had an alkalinity of only N/150. Following from this, alkali therapy has been used as an adjunct to surgery in the treatment of cases of severe gas gangrene, often with very marked beneficial results.

Antitryptic Power.—By this term is meant the capacity of the serum or lymph to neutralize tryptic ferments. It has been found that all serum has some antitryptic power, and that in certain conditions this is markedly increased. Sir Almroth Wright has shown that the men who were suffering from severe septic infections had a greatly enhanced antitryptic power in their blood fluids, and he has also pointed out the remarkable effect which the antitryptic power of the serum has on the growth of microbes in such serum. In serum of normal or raised antitryptic power, streptococci are the only microbes which grow at all freely when planted in small number. Staphylococci and some diphtheroid

bacilli will also grow to some extent, but not so well as streptococci. To these microbes, on account of their capacity of growing in unaltered serum, he has given the name of 'serophytes.' The other microbes found in wounds he has called 'sero-saprophytes,' as they grow badly in unaltered serum or lymph but flourish in such fluids when they have become 'corrupted.' It has been demonstrated that leucocytes when they disintegrate liberate a tryptic ferment. The discharges from a wound contain leucocytes in greater or less numbers. As a result of the toxic products produced by the bacteria in a wound, or the chemical substances introduced into the wound, some of these leucocytes are broken down, and tryptic ferments are liberated, which diminish the antitryptic power of the lymph or even render it tryptic, and so make it a good cultivation medium for all the microbes which are to be found in a wound.


Vaseline plug
Gas formed by growth of bacterium.
Serum culture
− 1/8 1/23 1/60 0 1/50 1/60 1/45 1/39 1/35 1/30 N +
Antitryptic power. (B. sporogenes.)
− 1/5 1/15 1/30 0 1/60 1/40 1/35 1/30 N +
Antitryptic power. (B. Welchii.)

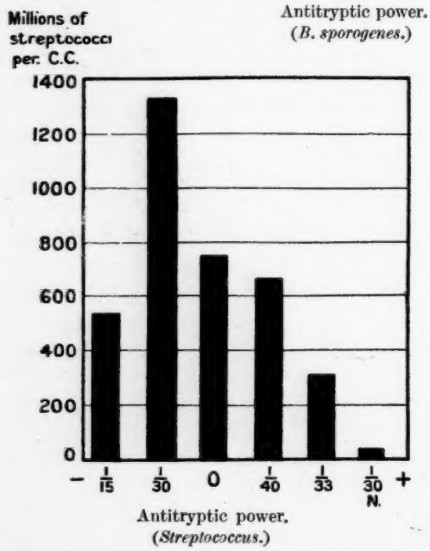


FIG. 111.—Effect of reducing the antitryptic power on the growth of bacteria in serum.

In the wound which has only been inflicted a few days, and in which there are sloughs present, the discharges are found to be either tryptic or to have a very greatly reduced antitryptic content, and in these wounds the flora is a very mixed one, anaerobic bacilli, aerobic bacilli, and pyogenic cocci being usually present. In the later stages, however, when the wound becomes clean and when the antitryptic power of the discharges is fairly high, there are usually to be found only streptococci, staphylococci, and diphtheroid bacilli, all of which are serophytes. Usually the last microbe to disappear from a wound is the streptococcus, and this is the one which grows best in the unaltered serum or lymph. *Fig.* 111 illustrates the effect of the antitryptic power on the growth in serum of *B. Welchii*, *B. sporogenes*, and streptococcus. Graduated additions of a solution of trypsin were here made to the serum, so that some of the tubes have a reduced antitryptic power, while others were actually tryptic. It will be seen that no growth has occurred in the unaltered serum with *B. Welchii* or *B. sporogenes*, although good growth and gas-formation took place when the antitryptic power was neutralized. With streptococcus a certain amount of growth was observed in the unaltered serum, but even with this organism the

growth was very greatly enhanced when a small reduction in the antitryptic content was made.

We can well see that to rid a wound of the serosaprophytic organisms, it is very necessary that the antitryptic power of the discharges should be kept at a high level, and that these discharges should be kept free from corruption. The blood in all these cases is possessed of a high antitryptic content, and if the discharges have a low antitryptic power, it means that the lymph has become corrupted by broken-down leucocytes in or around the wound.

A necessary preliminary to the prevention of this corruption is the removal of all sloughs from the wound. These, where they cannot be removed by surgical means, must be got rid of by tryptic digestion, and here we find ourselves in a dilemna. On the one hand we want the antitryptic power maintained to prevent the growth of organisms, and on the other it is necessary to rid the wound of sloughs by tryptic digestion. In practice it is found to be impossible, while sloughs are present, to maintain a high antitryptic content in the discharges, so that we must, in the early days of the wound, attempt to avoid disaster by means of free drainage of the cavity of the wound, and concentrate on removal of the sloughs. This is done most rapidly by means of an intermittent application of hypertonic salt solution. This solution immediately breaks up the leucocytes with which it comes in contact, and liberates trypsin. (It has no destructive effect on trypsin itself.) The salt solution soon becomes diminished in strength (*Fig.* 129), so that all inhibitory action on tryptic digestion is lost and the liberated trypsin can act without hindrance on the sloughs. Meantime, as soon as the strength of the salt solution approaches normal, fresh leucocytes emigrate into the cavity of the wound. These are destroyed with the next application of hypertonic salt, and so the process goes on until the wound is clear of sloughs.

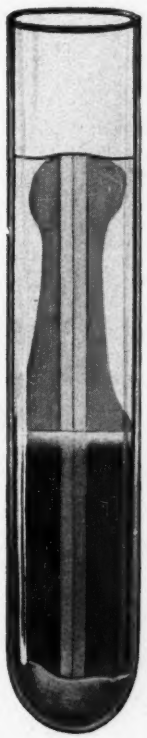


FIG. 112.– Glass laths in centrifuged blood, showing the red clot below, above this the leucocytic layer, and above this the white clot contracted round the laths.

While this is happening in the cavity of the wound, we must not lose sight of the events which are occurring in the infected walls, for it is here that the really serious infection exists. As a result of bacterial action, leucocytes are here also breaking down and corrupting the lymph, and it is very necessary that this corrupted lymph should be removed and be replaced with fresh fluid possessing its full antitryptic and antibacterial power. Drainage of the tissues around the wound is just as important as the mere mechanical drainage of the cavity of the wound, and it can most easily be effected by the application of hypertonic salt solution, which causes a prompt outflow of lymph from the tissues into the cavity of the wound (*Fig.* 133).

We shall see later that the benefit derived from some of the so-called antiseptics is, in all probability, due to their exercising an action in the wound with results similar to that obtained with hypertonic salt solution.

2. Leucocytes.—

It has long been known that the chief agents in the destruction of bacteria in a wound are the leucocytes. Recently, however, Sir Almroth Wright has devised methods which have shown their remarkable potency in this connection. We can show this first with leucocytes obtained from the blood. Blood in itself contains too few leucocytes and too much fluid for the bactericidal action to be manifest; but we can obtain an aggregation of the leucocytes from the blood in various ways, and so bring them to bear on the microbe in large numbers, more or less comparable with the condition of things in a wound.

Blood is drawn from the finger into a narrow tube (*Fig.* 112) containing a small glass slip (which we have called a 'lath'), and the tube is centrifuged before the blood has time to clot.

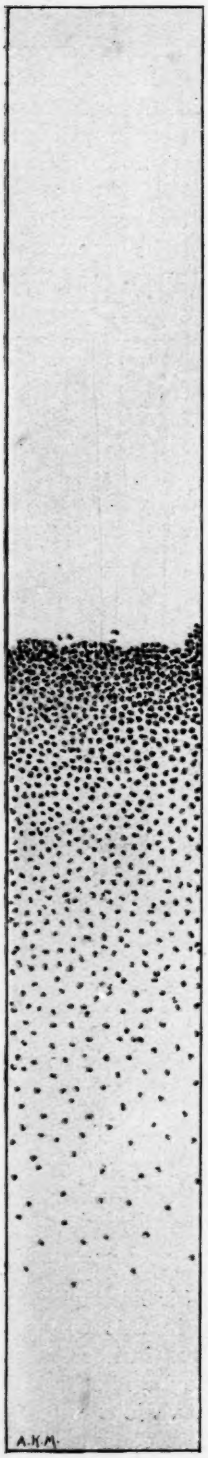
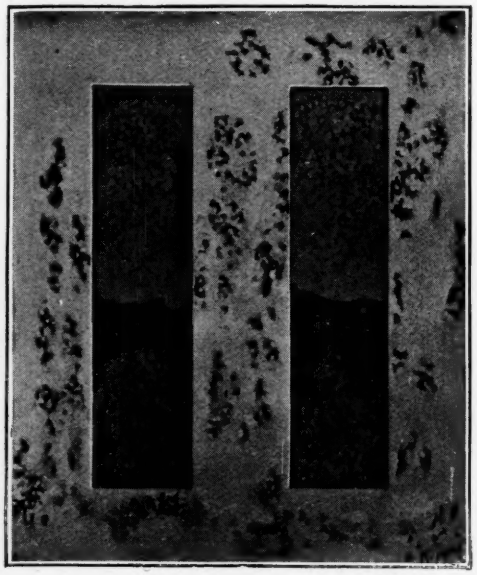


FIG. 113.—Emigrated leucocytes on a glass lath incubated in centrifuged blood for one hour.

We then have the condition represented in *Fig.* 112, i.e., the upper half of the tube is filled with plasma and the lower with corpuscles. The leucocytes, being of slightly less specific gravity than the red corpuscles, are to a certain extent aggregated in the upper layers of the corpuscular portion. If we now place the tube in the incubator for an hour, the leucocytes emigrate on to the glass lath and adhere to it, and if this lath is taken out, washed free from red corpuscles, and stained, it will be found that in the upper half, corresponding to the portion of the lath surrounded with plasma, there are no leucocytes. Towards the centre of the lath, corresponding with the upper corpuscular layer, there are an enormous number of leucocytes adhering to the lath, and these gradually diminish in numbers towards the bottom. If such a lath with the adherent leucocytes be placed on an infected agar plate, it will be found that



A *B*

FIG. 114.—Glass laths, such as are shown in *Fig.* 113, imposed on agar surfaces implanted with staphylococcus. In *A* the leucocytes were brought into operation in serum; in *B* in normal salt solution.

the microbes are completely destroyed in the region where there are many leucocytes, while there is no inhibition of growth under the upper half of the lath on which there are no leucocytes. The distribution of the leucocytes on the lath, and the bactericidal effect of these leucocytes, are shown in *Figs.* 113, 114,

It was found also that the leucocytes had the power of destroying the microbes even after they had been washed quite free from serum. In such a case no phagocytosis took place, yet there was a very definite direct bactericidal power exercised by the leucocytes (*Fig.* 114*B*).

We see, then, that leucocytes collected from the blood are powerful bactericidal agents, and it now remains for us to see whether the leucocytes obtained from an infected wound behave in the same way.

Very soon after the infliction of a wound, leucocytes commence to collect in the walls and emigrate into the cavity of the wound, ultimately forming the cellular elements of pus. It used to be taught that pus was a collection of dead leucocytes; but this only approaches accuracy when the pus is obtained from a collection which has stagnated and in which the leucocytes have been in contact with the bacteria for a considerable time. *Fig.* 115 illustrates the bactericidal power of such a pus, in which most of the leucocytes are dead. This pus came from an unopened furuncle. Some of the pus was placed on an agar plate and covered with a cover-slip, when the pus spread out in a thin film between the cover-slip and the agar. The plate was then incubated, and innumerable colonies developed throughout the pus, thus showing that the leucocytes had lost their bactericidal action.

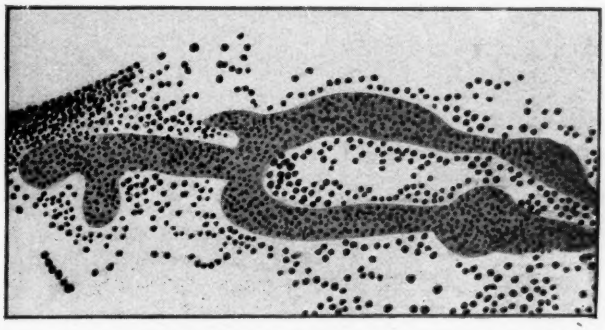


FIG. 115.—Bio-pyo culture. Pus from a furuncle spread out on agar under a cover-glass and incubated. Innumerable staphylococcus colonies have developed in the pus and in the surrounding liquor puris.

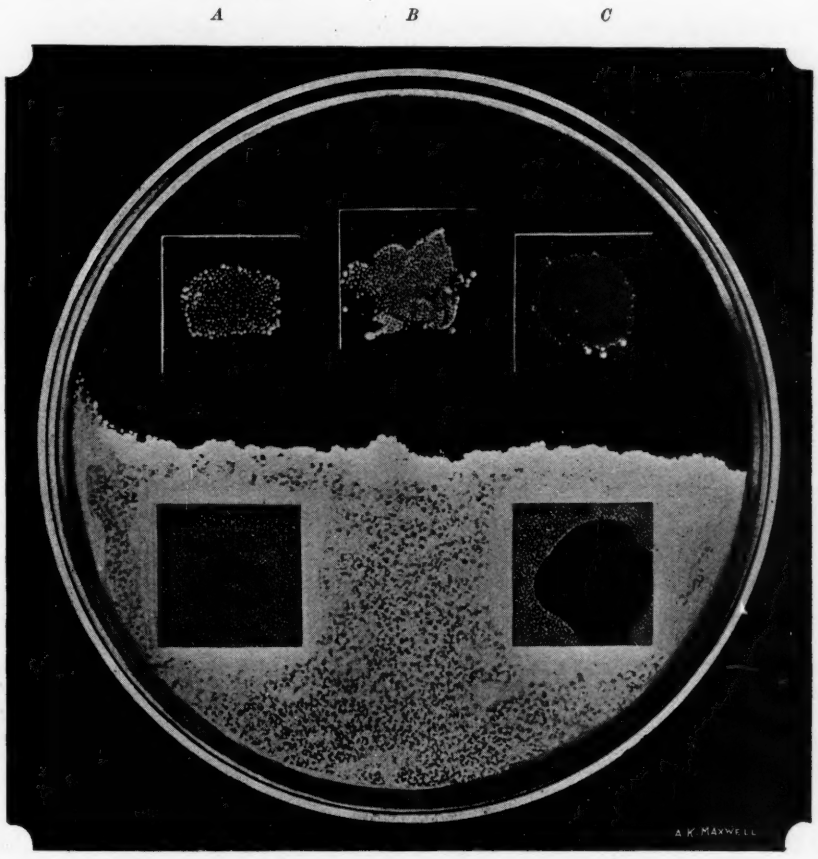


FIG. 116.—Drawing made after 24 hours' incubation of pus from a clean wound imposed under cover-glasses on sterile agar (*A*, *B*, *C*), and on agar implanted with staphylococcus (*D*, *E*). *A*, Pus heated to 48° C. *B*, Dried pus. *C*, Living pus. *D*, Pus heated to 48° C. *E*, Living pus.

This result should be contrasted with that illustrated in *Fig.* 116*C*, which represents fresh pus from an open wound treated in the same way. Here it will be seen that no colonies develop in the pus, but only a few colonies around the margin where some of the microbes have been squeezed out into the pus fluid and away from the reach of the pus-cells by the weight of the cover-slip. It will also be seen from *Fig.* 116*B* and *A* that when the leucocytes are killed by heating them to 48° C., or by drying, many colonies develop throughout the pus, giving a picture similar to that shown in *Fig.* 115 where stale pus was used.

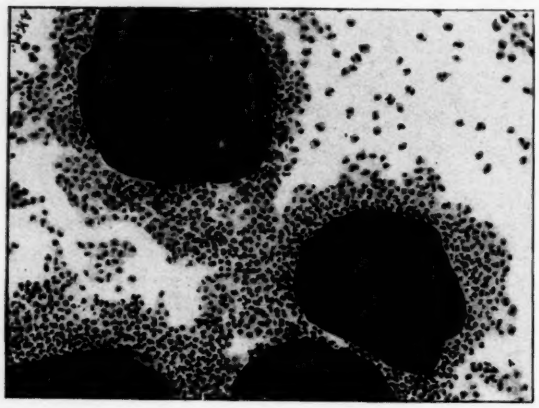


FIG. 117.—Leucocytes of pus aggregating themselves in dense rings round colonies of staphylococcus.

We have shown (*Fig.* 116*C*) that the cells of fresh pus can destroy the microbes contained in that pus, but they can do much more than this. If, instead of using a sterile agar plate, the pus is placed on an agar plate which has been heavily infected with staphylococci or streptococci, covered, and incubated, it will be found that the pus has completely destroyed the added cocci in addition to destroying its own microbes. This is shown in *Fig.* 116*E*, from which it will be seen that there is no growth where there is pus, but a very copious growth where the pus is absent. We see also from *Fig.* 116*D*

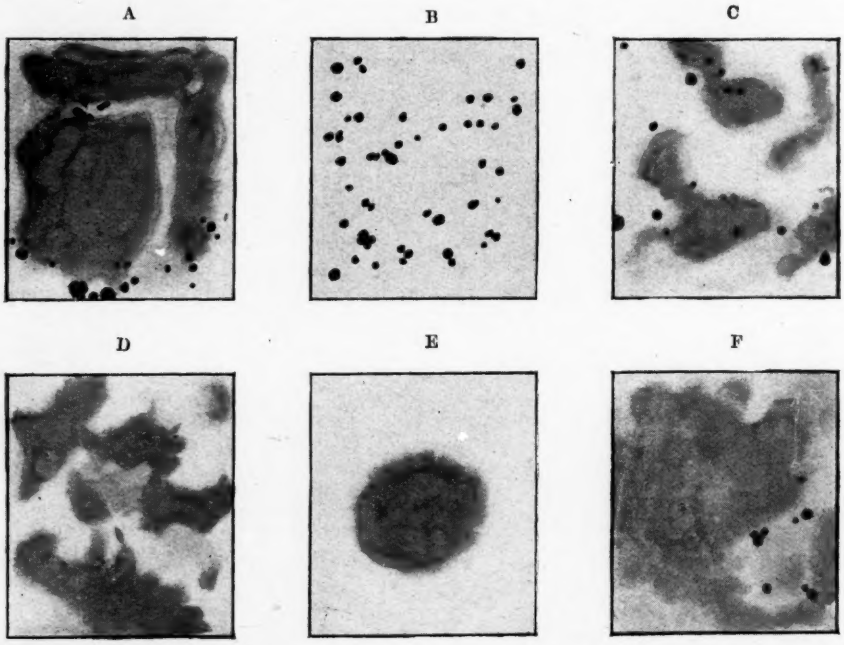


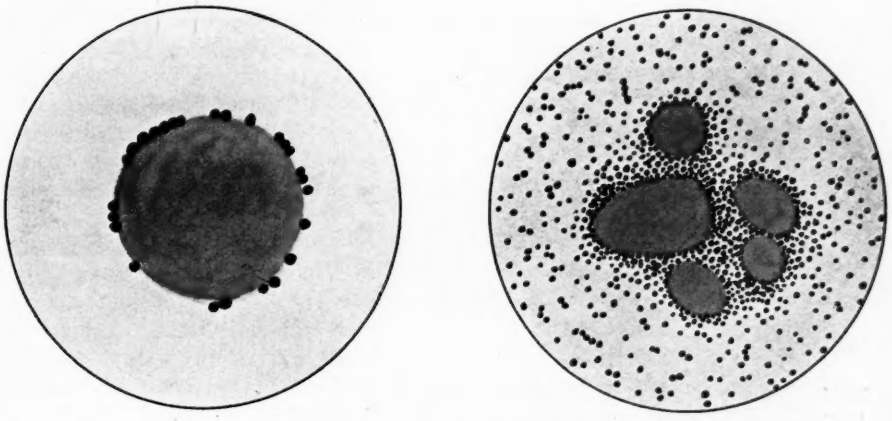
FIG. 118.—Impression cultures of a wound; A, Before washing with normal salt solution; B, Immediately after; C, 1½ hours after; D, 4 hours after; E, 8 hours after; F, 24 hours after.

that if the pus-cells are killed by heating to 47° C. there is no inhibition of the growth of these microbes.

In some cases it will be found that, even with fresh pus, one or two colonies will appear in the substance of the pus. *Fig.* 117 illustrates the microscopical appearance of

the stained cover-glass from such a specimen. It will be seen that there is an aggregation of leucocytes around the colonies, showing that there had been an attempt, although unsuccessful, on the part of the leucocytes to deal with the microbes.

If, instead of making a bio-pyo culture in the way described above, namely, by placing a small quantity of the pus on an agar plate and covering it with a cover-glass, the culture is made by dropping a sterile cover-slip on the wound and immediately transferring it to an agar plate, the result is the same. Few or no colonies develop where pus was adhering to the cover-slip, but they develop in the spaces between the islands of pus. This type of culture I have called an impression culture, and I have used it largely in studying the effect of washing a wound with various fluids, to which experiments reference will be made later. If impression cultures are made in a clean wound before washing with normal saline solution, and again at various times after (the wound meanwhile being covered with protective, so that the whole of the exudate may be retained), results are obtained such as are illustrated in *Fig.* 118. Before the dressing a number of colonies develop between the pus islands. Immediately after the dressing there are many more colonies, as most of the pus cells have been washed away by the saline, but many microbes remain and can grow unhindered. A specimen taken an hour and a half after dressing still shows a few colonies, but the four-hour and eight-hour specimens remain sterile, as here the freshly emigrated leucocytes are capable of dealing with the infection. (That living microbes were



A. *B.*

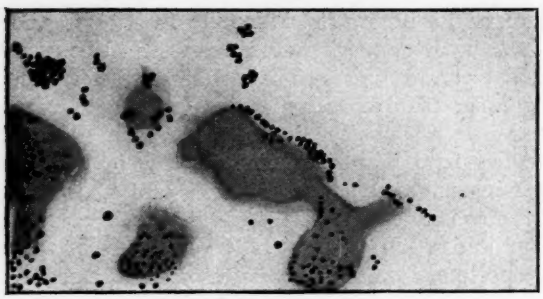
FIG. 119.—Bio-pyo cultures from clean wound. *A*, Pus unaltered; *B*, Same pus mixed with serum.

still present in these specimens when removed from the wound was shown by heating the pus to 47° C. and then placing it under a cover-slip on an agar plate, when many colonies developed throughout the pus.) The specimen taken twenty-four hours after dressing shows practically the same condition as the first specimen. This change from the eight-hour to the twenty-four-hour specimen is probably due partly to the degeneration of some of the cells and partly to the collection of fluid under the protective. The leucocyte does not swim freely in fluid, but apparently only shows active movement when it has some point of attachment, so that in any fluid collection it only exercises its functions fully on the walls of the cavity. A consideration of this is of the greatest value in wound treatment, as it explains why it is necessary to bring the surfaces together in suturing these wounds to obtain healing without suppuration, and why it is that in cavities which normally contain fluid, or into which fluid is rapidly poured as a result of an infection of pyogenic cocci, such an infection tends to have very grave results. The body fluids have normally no bactericidal action on these cocci, and the leucocytes do not have a fair chance of combating the invasion in the presence of much fluid. The effect of excess of fluid in diminishing the effective bactericidal power of the leucocytes can be shown in two ways. Bio-pyo cultures are made with pus as it is removed from the wound, and with the same

quantity of pus to which has been added an equal quantity of sterile serum. It will be found that, in the case where the pus has been diluted with serum, a large number of colonies develop, as many of the microbes find their way into the fluid out of the reach of the leucocytes. This is illustrated in *Fig.* 119.

Fig. 120 shows the result of impression cultures made from the same wound on successive days. On the first and third days (A and C) the wound had been covered for twenty-four hours with impermeable protective which retained the discharges on the surface of the wound. Here it will be seen that a fair number of colonies have developed, especially between the islands of pus. On the second day (B) the wound was covered with a thick layer of absorbent gauze, which immediately soaked up the fluid portion of the discharge and provided a framework for the leucocytes so that they could function without disability. Here we see that the impression culture was almost sterile. On the fourth day this was repeated, with the same result. We see, therefore, that for a flat granulating surface a covering of absorbent material is of great advantage, and it has also been found by experience that if it is desired to suture a wound, close apposition of the surfaces is essential to success.

A



B

C

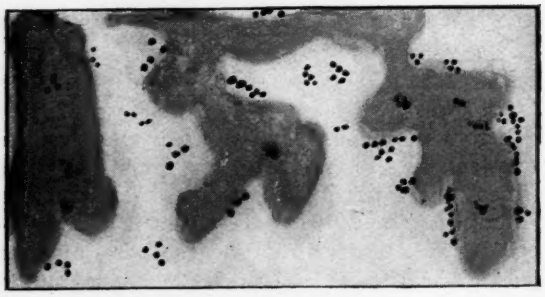


FIG. 120.—The description will be found in the text.

So far I have confined myself almost entirely to local conditions. We have seen that in the early stage it is of prime importance to clean the wound of sloughs and to drain the tissues, in addition to draining the cavity of the wound. In a later stage we have seen that we must make such conditions that the leucocytes can exert their maximum effect on the bacteria. We can, however, by the administration of vaccines in appropriate doses, assist the local defences by raising the antibacterial content of the blood fluids.

The organism which is responsible for almost all the serious infections of war wounds after the first few days is the *Streptococcus pyogenes*, just as it is of wounds in civil practice. For the last twelve or thirteen years streptococcus vaccines have been used for all manner of streptococcal infections with considerable success. One of the most striking series of cases was that published by Western[2]. This consisted of 56 cases of puerperal septicæmia, in all of which the streptococcus was obtained from the blood. By the use of vaccines he obtained 45 per cent of recoveries, as against about 10 per cent in the control cases of a similar nature not treated with vaccine.

In patients with septic wounds it is very common after an injection of streptococcus vaccine to see a drop in the temperature for one or two days, while the patient has a

general feeling of well-being. After a very considerable experience of vaccines in these cases, I feel strongly that no harm would result, but much good would follow, from the routine weekly administration of stock streptococcus vaccine in doses of from 1 to 5 million to all men with septic wounds. This streptococcus vaccine might be combined with vaccines of staphylococcus, *B. proteus*, or *B. pyocyaneus*, if they were found to be present in the wound. All vaccine treatment must, however, be secondary to proper local treatment of the wound.

ANTISEPTIC TREATMENT.

The teaching of the 'antiseptic' school is that one should aim at the sterilization of a wound with a single application of the antiseptic; failing this, it is held that the antiseptic, even if it does not completely sterilize the wound, will kill a large number of the microbes present, so that it will at least diminish the amount of the infection, and will leave a medium in the cavity of the wound in which the microbes will not flourish. It is further held that, provided the antiseptic is used in dilute solution, no damage will be done. We shall see how these teachings bear the light of experiment.

We must first, however, consider the action of these chemical antiseptics on bacteria and on leucocytes outside the body (see *Tables I, II, III*). I shall have nothing to say here regarding the action of these antiseptics on bacteria in a watery medium, as this has no bearing on their bactericidal action in an infected wound. Speaking generally, it has been found that antiseptic solutions show their maximum bactericidal action when they are allowed to act on the microbes in a watery medium; their action is more feeble when the medium is of a serous character; it is still less in blood; it is further reduced when the medium is of a purulent nature; while least of all will an antiseptic act on bacteria embedded in a piece of tissue.

Table I.—Inhibitory Power of Antiseptics on the Growth of Bacteria in Serum.

Antiseptic	Concentration which completely inhibits growth of					
	B. Welchii	B. sporcgenes	B. pseudotetanus	B. proteus	B. coli	Staphylococcus
Carbolic acid ..	1–200	1–200	1–200	1–200	1–200	1–200
Mercuric chloride ..	1–2000	1–2000	—	1–8000	1–16,000	1–8000
Iodine	1–500	1–500	1–500	1–500	1–500	1–500
Eusol	1–4	+ 1–2	+ 1–2	1–8	1–4	1–8
Dakin's solution ..	+ 1–2	+ 1–2	+ 1–2	+ 1–2	—	—
Chloramine-T. ..	1–60	1–50	1–80	1–50	—	—
Flavine	1–16,000	—	—	1–1000	1–500	1–16,000* / 1–60,000†
Brilliant-green ..	+ 1–1000	—	—	—	1–1000	—
Malachite-green ..	1–200	+ 1–200	+ 1–200	+ 1–200	+ 1–200	—

* If the infection is a heavy one. † If the infection is a light one.
\+ = Greater than.

Table II.—Bactericidal Action of Antiseptics in Pus.

Antiseptic	Lethal Concentration
Carbolic acid ..	1–50
Lysol	1–50
Iodine	1–400
Boric acid	+ 1–50
Hydrogen peroxide ..	0
Flavine	1–500
Eusol	3–1
Dakin's fluid ..	3–1

\+ = Greater than.

Table III.—Effect of Antiseptics on Leucocytes.

Antiseptic	Greatest Concentration which allows Emigration	Concentration which inhibits Phagocytosis by 50 per cent after exposure for			
		20 minutes	2 hours	5 hours	24 hours
Carbolic acid ..	1–1600	1–500	1–1600	1–1,600	1–2000
Mercuric chloride ..	1–16,000	1–7000	1–16,000	1–16,000	—
Iodine	1–1200	—	1–500	1–1,000	1–1000
Eusol	1–8	—	1–4	1–4	1–8
Dakin's solution ..	1–16	—	1–16	1–16	1–16
Flavine	1–4000	1–500	1–1000	1–500,000	1–2,000,000
Brilliant-green ..	1–16,000	1–7000	—	1,–20000	1–160,000
Malachite-green ..	1–16,000	1–7000	1–6000	1–12,000	1–100,000
Crystal-violet ..	1–16,000	1–7000	—	—	—
Picric acid	1–800	—	—	1–400	1–800

In *Table I* are set forth the results I have obtained in testing the inhibitory power of the common antiseptics on the growth of bacteria in serum, and in *Table II* the concentrations which are necessary to kill the bacteria in pus, while *Table III* shows the strengths of antiseptic which inhibit leucocytic emigration and destroy the phagocytic power of the leucocytes.

These tables must be considered together; but before drawing any conclusions as to the value of this or that antiseptic in the treatment of a septic wound, certain very important factors, which do not appear in the tables, must be taken into account. One of the most important of these is the rate at which the antiseptic acts on the bacteria and on the leucocytes. The antiseptics which act rapidly on the bacteria will also act rapidly on the leucocytes, and any comparison of the value of antiseptics based on their action on bacteria and leucocytes will be quite fallacious unless the chemical is allowed to act on both bacteria and leucocytes for the same time, and unless such a time is chosen as is to some extent comparable with the time during which the chemical will remain active in the wound. The rate at which the antiseptic is destroyed in the wound is also of prime importance, and if a slow-acting antiseptic is rapidly destroyed in the wound, it is unlikely that it will exercise a marked bactericidal effect. The hypochlorites act very rapidly, but they are quenched almost immediately. Flavine, on the other hand, acts very slowly, but much of it is rapidly used up in dyeing the walls of the wound and the dressing.

Can a wound be sterilized by a single application of an antiseptic?

Fig. 121 represents diagrammatically the relation of the bacteria to the tissues soon after the infliction of the wound, and at a later stage when the infection has become established. In the recently inflicted wound, before the infection has grown out, the microbes are scattered throughout the wound in small numbers, either free or enclosed in pieces of earth or clothing. They are confined to those portions of the wound where they have been deposited by the missile. In the later stage, however, where the infection has grown out, the microbes are spread throughout the whole cavity and they have penetrated into the walls of the wound for a considerable depth.

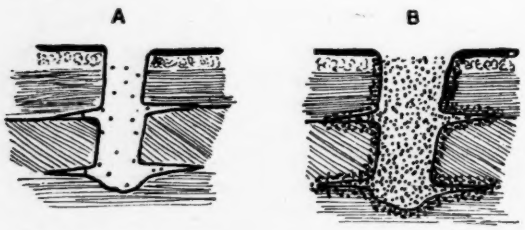


Fig. 121.—Diagram of a wound. A. Recently inflicted. B, After infection has become established. The dots in the cavity in A and in and around the cavity in B represent microbes.

It was very early found that no antiseptic was capable of sterilizing by a single application a wound in which the infection had become established. It will be seen from *Tables I, II,* and *III* that the leucocytes are more sensitive to the action of chemical antiseptics

than are the bacteria, and, in view of this, it is unlikely that any of these antiseptics have the power of penetrating into the tissues and destroying the bacteria without first killing the tissues themselves.

I have attempted to imitate a wound in which the infection is limited to the cavity, by means of a tube such as is depicted in *Fig.* 122A, which has several small processes drawn out to represent the diverticula which exist in all serious recently-inflicted gunshot wounds. Into such a tube is placed some serum which has been implanted with fæces, and which makes a fair imitation of the primary infection of a wound. After this had been incubated so that the infection might spread throughout the whole tube, I tried to sterilize it with some of the antiseptics in common use. The procedure adopted was to pour out the contents and wash the tube three or four times with the antiseptic solution by filling the tube with it and emptying it out again. Then the tube was filled with the antiseptic solution and left for twenty minutes, after which the antiseptic was poured out and replaced by serum. The tube was then incubated for twenty-four hours. The result was that there was no change in the flora of the tube on the second day. The next day I 'dressed' it in the same way, but left the antiseptic in the tube for one hour. This had no effect. The next day the antiseptic was left in the tube for three hours, but it likewise had no effect. Then the antiseptic was allowed to remain in the tube for twenty-four hours, after which it was emptied out, replaced by serum, and the tube incubated as before. Films were made of the contents of the tubes, and the microscopic appearance of these films is shown in *Fig.* 122, B to F, from which it will be seen that there is practically no difference between the tube dressed with normal saline and those in which antiseptic solutions were used. This would seem to indicate clearly that it is impossible to sterilize a wound with an antiseptic, even if it were possible to keep the antiseptic solution in the wound for a long time without dilution, and even if the walls of the wound were not infected. I have carried out the same experiment with brilliant-green and flavine, and found both equally unsuccessful.

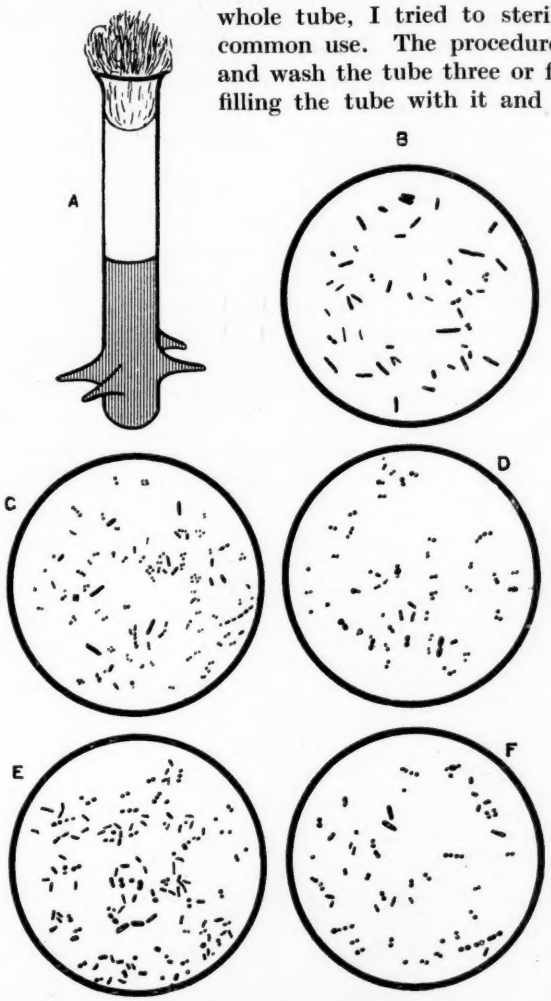


FIG. 122.—A, Artificial wound; B to F, Microscopical appearances of the serum in the artificial wound after being 'dressed' for several days with (B) normal salt solution, (C) 5% salt solution, (D) eusol, (E) Dakin's solution, (F) carbolic acid 1–40.

I tried to imitate the infected walls of the wound by placing a ball of infected asbestos-wool, about the size of a pea, in a test-tube, and I then attempted to sterilize it by filling the tube with Dakin's solution, which was changed at intervals during twenty-four hours. Then the Dakin's fluid was emptied out, and the tube filled with serum and incubated. The tube which had been treated with Dakin's solution gave as good a growth as the control tube which had been treated with normal salt solution, and, on examining the growth under the microscope, there was found to be no change in the original flora.

Even if it does not completely sterilize a wound, does the antiseptic at least kill some of the microbes and so reduce the active infection in the wound?

There can be no reasonable doubt that antiseptic applications kill some of the microbes in the cavity of a wound, but it does not follow from this that the active residual infection should be any less. As we have seen, the problem in an infected wound is not a simple one. In addition to any chemical antiseptic we employ, there is a very powerful antiseptic effect being constantly exercised by the protective agencies of the body. The most powerful of these is the leucocyte, which is to be found both in the cavity and the walls of the wound. We have already seen, in the consideration of the experiment illustrated in *Fig.* 116, something of the power of this natural antiseptic. Now if the chemical antiseptic solution employed, in addition to killing some of the microbes in the cavity of the wound, also destroys the leucocytes (and a consideration of *Tables I* and *III* will show that the leucocytes are more susceptible to the action of these chemicals than are the bacteria), then the result on balance may well be that there are actually more microbes that can grow and flourish after the application than there were before.

Observations were made on a wound of medium severity which was exuding much pus and which was being treated with two-hourly irrigations of eusol through Carrel's tubes. Just before one of the irrigations a pipette was introduced along the side of the Carrel tube, and some of the pus was withdrawn. The wound was then irrigated with eusol by the surgeon in the usual way, and five minutes afterwards a pipette was again introduced along the wall of the tube as nearly as possible in the same situation as before, and some of the purulent discharge was withdrawn. The same quantity of each of these two samples of pus were placed on an agar plate and covered with cover-glasses, after which the plate was incubated.

Fig. 123 represents the resulting growth of microbes from pus before and after irrigation, and it will be seen that, so far from there being any diminution in the number of colonies, there is rather an increase in the latter.

Before. 5 minutes after.

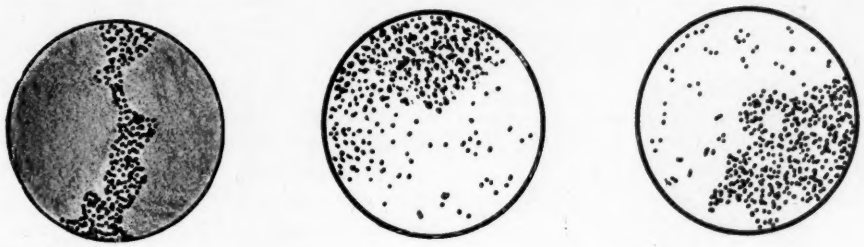
FIG. 123.—Bio-pyo cultures made before and after irrigation of a wound with eusol.

Again, if a clean flat granulating wound be taken and impression cultures be made before and after the application of any of the common antiseptic solutions, it will be found that the amount of growth obtained after the application is greater than it was before. This is shown in *Fig.* 124.

A clean, flat, granulating wound such as this, without pockets or macroscopic sloughs, should be absolutely the most favourable for the observation of any antiseptic action which a fluid may possess. Yet we see that, so far from sterilizing the wound, the growth obtained, even from the surface, is much greater after than it was before the application of the antiseptic. The natural antiseptic powers of the pus are done away with, but the microbes are not completely destroyed, and those which are left are allowed to grow unhindered until such time as fresh pus-cells can emigrate to keep them in check.

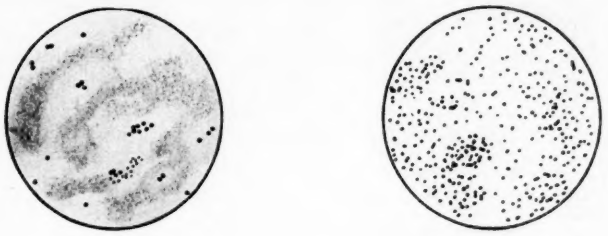
A consideration of the leucocidal property of antiseptics will show us that certain antiseptics are suitable for the washing of a wound, while others are bad. We can take it as certain that these antiseptic solutions will kill the leucocytes in greater dilution than they will the microbes. If we desire, therefore, an antiseptic solution with which to wash

out a wound, we should choose one which loses its antileucocytic power rapidly and which exercises its antiseptic action very quickly. We then have the washing effect of the fluid without doing much damage to the wound. If, however, we use an antiseptic which will



A *B* *C*

A, Before washing. *B*, After washing with carbolic acid (1-40). *C*, After eusol following carbolic acid (1-40).

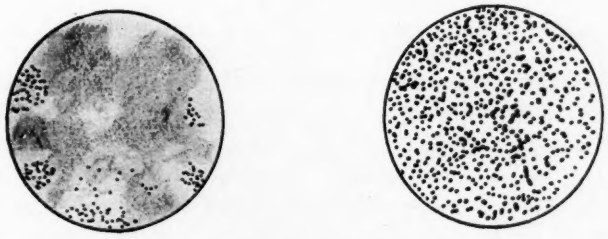


Before After

Eusol.

Before After

0·05 Perchloride of mercury.



Before After

Peroxide of hydrogen.

FIG. 124.—Impression cultures from granulating wounds before and after irrigation with antiseptics.

only gradually disappear, we shall have a considerable interval during which the fluid has no lethal effect on the microbes, while it will completely inhibit the leucocytes within its sphere of action. There is also the question of the stimulation of the growth of microbes by weak solutions of these chemical antiseptics, which will be considered in the next section.

There is only one way in which I have been able to sterilize the surface of a flat granulating wound by means of a chemical antiseptic. Such a wound was taken and divided into two halves. One half was washed with normal saline and the other with eusol; impression cultures were then made, and it was found that there was no very great difference between the two halves (*Fig.* 125, B, C). The whole wound was then washed with eusol, and cultures were again made from the two halves, when it was found that the part which had been originally washed with saline was sterile (E), while the half which had been washed twice with eusol still gave a growth (D).

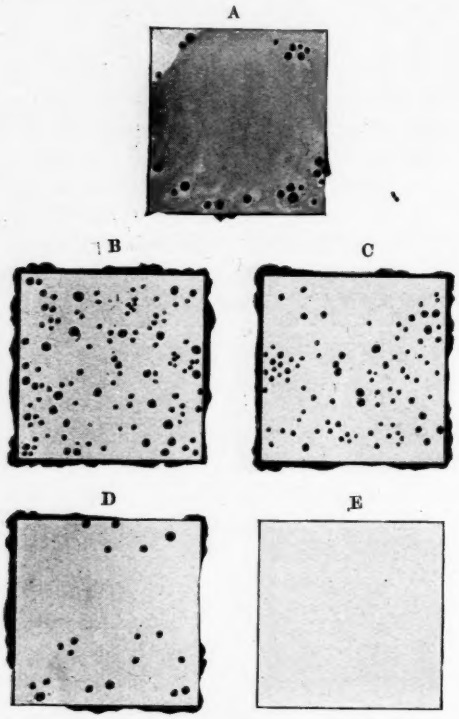
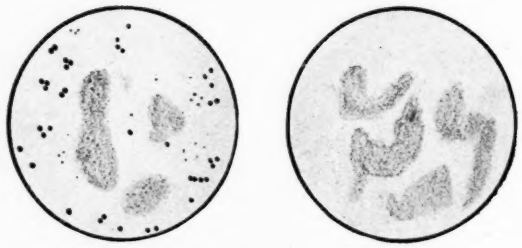


FIG. 125.—B-iopyo-culture from clean wound, and cultures made from it after washing with eusol and physiological salt solution. Description in text.

A preliminary wash with carbolic acid before the eusol did not enable the latter to sterilize the surface (*Fig.* 124). It would seem that the saline solution removed the albuminous material from the surface of the wound, and then the eusol was able to act on the bacteria in practically a watery medium, in which it is very active; this would seem to be the best way of ridding the surface of a wound of bacteria.

One great advantage of eusol and Dakin's solution is that they disappear as active



½ hour after. 4 hours after.
Eusol irrigation.

FIG. 126.—Impression cultures of a wound.

chemical agents in a few minutes and do not have any lasting deleterious effect on the leucocytes. This is shown in *Fig.* 126, which shows the results of impression cultures from a wound at intervals after washing with eusol. It will be seen that four hours after dressing, the culture remained sterile, showing that, during this interval, fresh leucocytes had emigrated in sufficient numbers to deal with the microbes on the surface of the wound.

Will the antiseptic application leave in the wound a medium which will inhibit the growth of microbes?

We have seen above that the antiseptics have potentialities for harm, in that they destroy leucocytes in a less concentration than that in which they will kill microbes. They may have yet another action which must be considered—the stimulation of the growth of microbes in serum by these chemicals. In experiments on this subject, we have used as a medium serum to which has been added trypsin sufficient to neutralize the antitryptic power of the serum or actually to render it tryptic. This is an imitation of the condition of things found in pus fluids. The serum was implanted with microbes, and then the antiseptic was added in various dilutions. Usually we have taken microbes which produced gas from serum, as this rendered the experiment easier in that the amount of gas produced gave an indication of the amount of growth of the microbe. The experiments were carried out in small test-tubes, and, as soon as the mixtures were made, melted

vaseline was poured on the top of the fluid in the tube and allowed to set. The gas, as it was produced by the growth of the microbe, pushed up the vaseline plug so that the total amount of gas produced could readily be measured. *Fig.* 127 illustrates this method, which was introduced by Beattie.[3] This figure also shows the effect of carbolic acid on the growth in serum of *B. Welchii*. It will be seen that growth is completely inhibited by 0·5 per cent of carbolic acid, but there is a regular rise in the amount of gas-formation

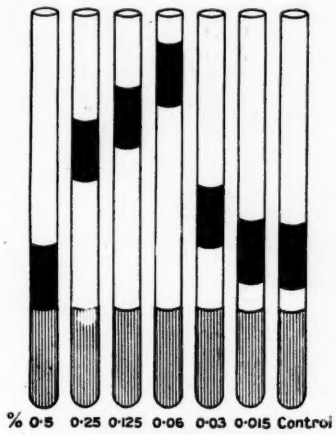


FIG. 127.—Influence of carbolic acid on the growth of *B. Welchii* in serum.

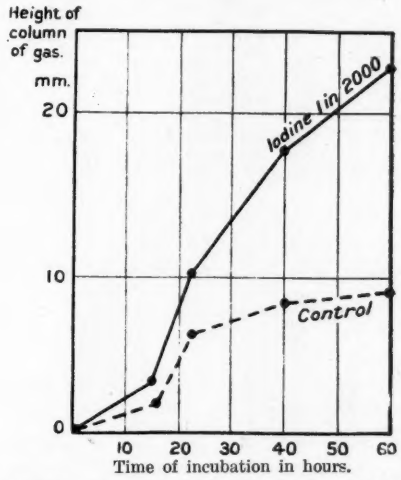


FIG. 128.—Curves of gas formation by *B. Welchii* in serum and in serum containing iodine 1-2000.

up to a maximum in the tube containing 0·06 per cent carbolic acid, after which the amount of gas formed is less ; but even in the tube containing 0·015 per cent there is rather more gas-formation than in the control tube which contained no carbolic acid.

The results of this method can also be registered in the form of a chart by recording the amount of gas-formation after varying times of incubation. Such a chart is shown in *Fig.* 128, which depicts the rate of gas-formation by *B. Welchii* in serum and in serum containing iodine 1–2000.

It is not to be assumed, however, that every antiseptic will aid the growth of every microbe. The diagrams (*Figs.* 129A to H) show the effect of antiseptics on the growth of bacteria in serum. The height of the columns indicates the amount of gas

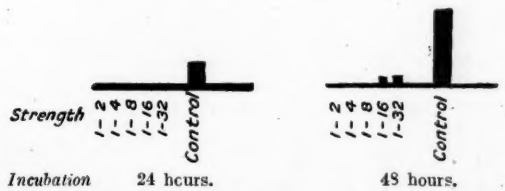


FIG. 129A.—Effect of eusol on the growth of *B. Welchii* in serum

produced by the organism growing in serum containing the concentration of antiseptic indicated. In every case there was no antiseptic in the control tube, this being replaced by normal salt solution. Dakin's solution and eusol will be seen to act only as inhibitants for *B. Welchii*, whereas both of these solutions strongly favour the growth of *B. sporogenes*. In the experiment illustrated where *B. sporogenes* was grown in eusol and serum, the amount of the bacillus was small, so that it was some time before growth proceeded far enough to manifest itself by gas-formation. In this experiment growth was first noticed in the tube containing equal parts of eusol and serum on the third day,

whereas in the control tube without eusol, gas-production only started on the eighth day. During the prolonged latent period in this experiment some change in the serum was probably taking place which was necessary for the growth of *B. sporogenes*, and it would appear that the eusol had hastened this change.

This experiment is, in some ways, comparable with what happens in a wound in the early stages, where there is only a small implantation of bacilli into a medium consisting

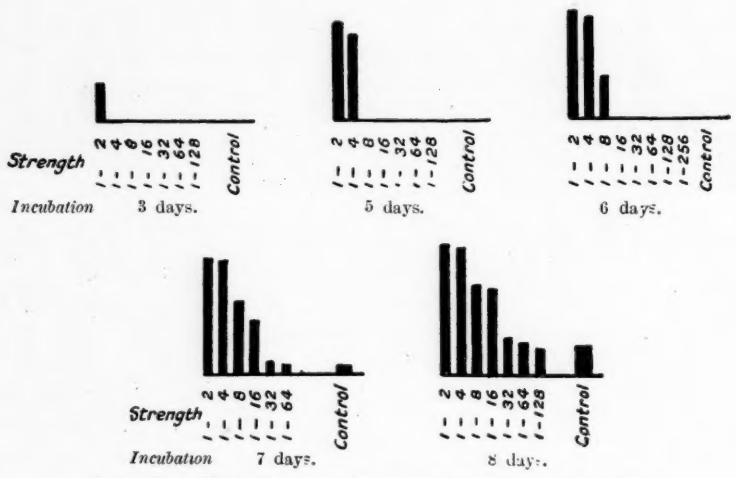


FIG. 129B.—Effect of eusol on the growth of *B. sporogenes* in serum.

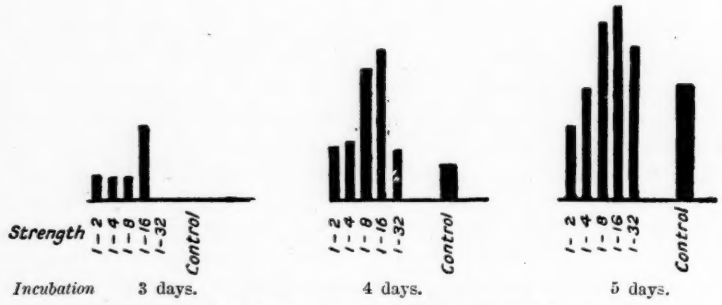


FIG. 129C.—Effect of eusol on the growth of pseudo-tetanus bacilli in serum.

FIG. 129D.—Effect of Dakin's solution on the growth of *B. Welchii* in serum.

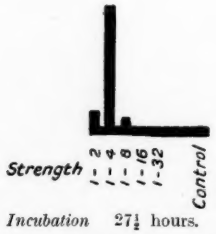


FIG. 129E.—Effect of Dakin's solution on the growth of *B. sporogenes* in serum.

largely of blood and serum, and it seems possible that the introduction of eusol into such a wound would hasten the growth of *B. sporogenes*, which is an almost universal primary infection.

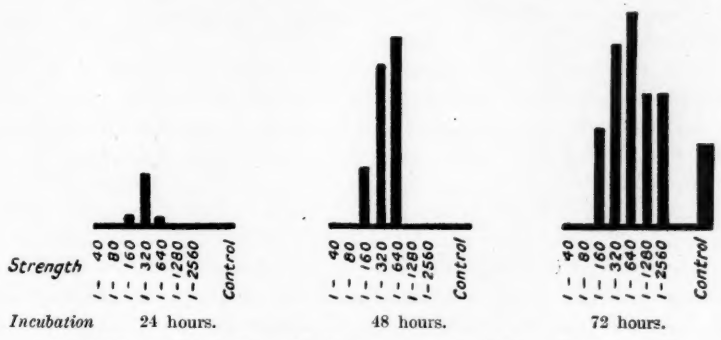


FIG. 129F.—Effect of chloramine-T on the growth of *B. sporogenes* in serum.

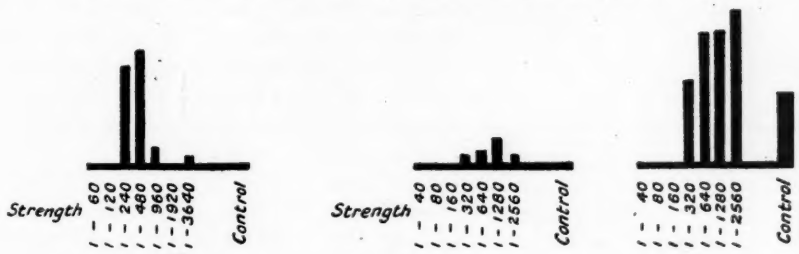


FIG. 129G.—Effect of chloramine-T, (*a*) on the growth of *B. Welchii* in serum; (*b*) on the growth of *B. proteus* in serum.

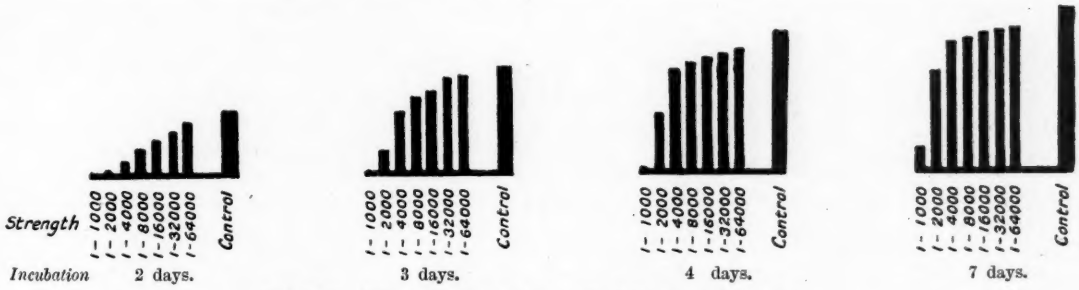


FIG. 129H.—Effect of iodine on the growth of *B. sporogenes* in serum.

From the foregoing experiments we can draw the following conclusions :—

1. It is not possible to sterilize a septic wound with a single application of any of the commonly used antiseptics.
2. Although, doubtless, the antiseptic kills some of the microbes in the cavity of the wound, it also inhibits the leucocytes, so that the active residual infection may actually be increased.
3. The antiseptic does not, of necessity, leave in the wound a medium which is inhibitory to the growth of microbes; on the contrary, it may have a stimulating effect on their growth.

PHYSIOLOGICAL ACTION OF ANTISEPTIC SOLUTIONS IN A WOUND.

In the study of antiseptics for wound treatment the action of the antiseptic on bacteria has been largely followed; but comparatively little attention has been paid to the physiological action of these solutions. I have attempted to make some observations on these lines by using cup-shaped wounds into which I could place a known

volume of fluid, and from the cavity of which I could remove the *whole* of the fluid. In this way I was enabled to ascertain something of the fate of the antiseptic solutions when introduced into a wound, the nature of the physiological reaction of the tissues to such fluids, and the bactericidal effect of the solutions *in vivo*.

Wounds suitable for such experimentation were rare, but I was able to make a series of observations on two wounds of very different character. Both were of old standing; one had a floor of necrosed bone, and from this wound there was a very copious purulent exudate; whereas the other was completely lined with granulation tissue, and there was only a moderate exudate of a serous character. The first wound also was heavily infected with a very mixed flora, while the second was only lightly infected with pyogenic cocci.

The procedure adopted was, in the morning, to empty the cavity completely of the exudate which had collected over-night, and then allow it to collect for a given time (usually about one hour), after which the cavity was completely emptied and the amount of exudate measured. This gave a base line of the amount of natural exudate on the particular day, and also gave information as to the nature of the exudate. The wound was then thoroughly cleansed with normal salt solution until the washings were quite clear, after which a known quantity of the solution on which observations were being made was introduced and left for five minutes. Then the cavity was completely emptied with a pipette, and a fresh volume of the fluid was introduced and removed after ten minutes. This procedure was repeated for longer and longer intervals, the portions of fluid being carefully collected and measured. During the time the fluid was in the wound it was not disturbed, so that really the changes observed were less than they would be in a wound where the fluid is spread in a thin layer over a large surface.

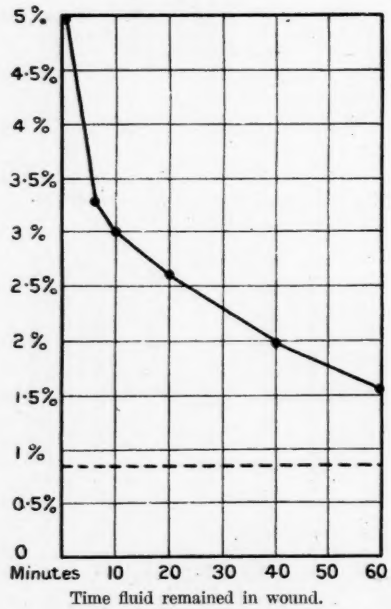


FIG. 130.—Diminution in concentration of 5 per cent saline solution in a wound.

Rate of Disappearance of the Active Agent.—

Physiological Salt Solution.—The salt content of this fluid remained unchanged.

Hypertonic Salt Solution.—The rate of diminution in the concentration of the salt is shown in *Fig.* 130, from which it will be seen that there is a gradual reduction in the strength, so that after one hour it has become reduced from 5 per cent to 2 per cent.

Eusol.—The amount of hypochlorite present in the solution was titrated with potassium iodide and sodium thiosulphate, and the results obtained are shown in *Fig.* 131. The original titre was 0·4 per cent, but this was reduced in five minutes to less than 0·1 per cent. A reference to *Tables I* and *II* will show that this concentration is almost without antiseptic value in serum or pus. In another experiment, in which the eusol was kept agitated during the whole time it was in the wound, the strength had diminished from 0·4 per cent to 0·16 per cent in one minute and to 0·04 per cent in five minutes. (This experiment is recorded in *Fig.* 131 as a broken line.)

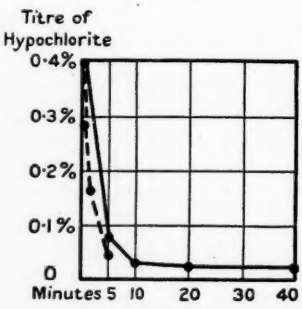


FIG. 131.—Rate of destruction of eusol in a wound.

Dakin's Solution.—This was titrated in the same way as eusol. The results are shown in *Fig.* 132, from which it will be seen that after five minutes the strength had fallen from 0·5 per cent (the original strength) to 0·13 per cent, and after ten minutes to

0·11 per cent. Reference to *Tables I* and *II* will show that after five minutes this solution possesses little, if any, bactericidal power in serum or pus. It is to be noted also, in connection with *Fig.* 132, that after a few seconds (less than half a minute) the strength had fallen from 0·5 per cent to 0·22 per cent of hypochlorite.

Chloramine-T.—This was tested by a method which proved unsatisfactory. It showed, however, that after ten minutes there was an enormous reduction in the strength of the chloramine-T solution.

Flavine.—The strength of this substance was tested by matching the colour of the fluid removed from the wound with solutions of flavine of a known strength. The original strength was 1–1000, and this was reduced after a few seconds to 1–1500, after thirty minutes to 1–2000, after sixty minutes to 1–3000, after two hours to 1–3500, and after fifteen hours and a half to 1–16,000.

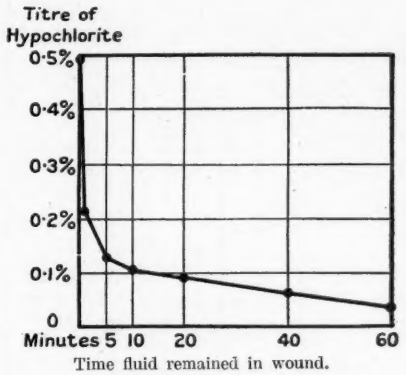


FIG. 132.—Rate of destruction of Dakin's solution in a wound.

Amount of the Exudate.—*Fig.* 133 shows the rate of exudation per hour from the wound before the application of the fluid, during the time the fluid is in the wound, and again for various times after the fluid had been removed. It will be seen from this that there is a very great increase of the exudate into hypertonic salt solution, and for a short time (less than thirty minutes) after the wound has been emptied of this solution. The increased exudate after the removal of the salt solution is due to the presence of salt in hypertonic solution in the walls of the wound, as the exudate removed thirty minutes after withdrawal of the salt solution was distinctly hypertonic.

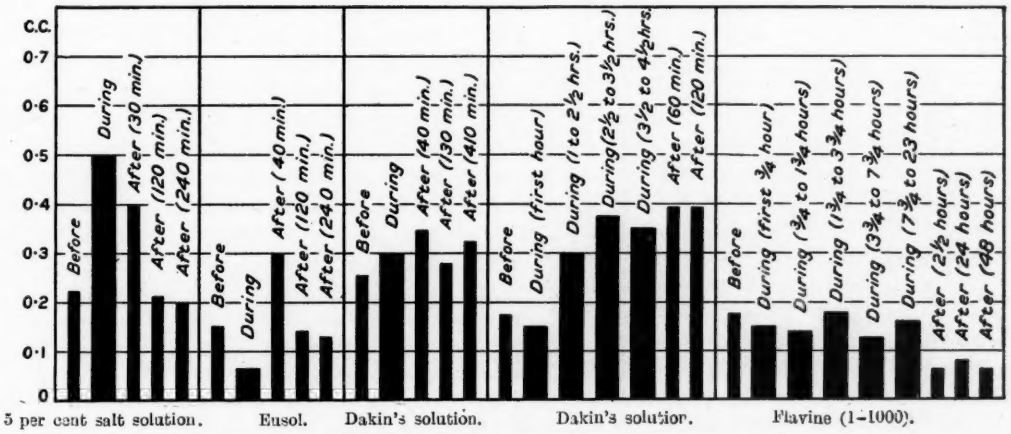


FIG. 133.—Transudation of fluid per hour into a wound cavity before, during, and after the application of salt solution, eusol, Dakin's solution, and flavine.

With eusol there is some diminution of the exudate while the eusol is in the wound (for one hour), but this is followed by a very considerable increase for a time (less than forty minutes) after. When Dakin's solution was placed in the wound for one hour there was a slight increase in the rate of exudation into the Dakin's solution, and this was followed by a further increase for forty minutes after. When, however, Dakin's solution was applied in four changes extending over four and a half hours on the following day, there was a marked increase in the last three and a half hours during which the solution was in the wound, and the rate of exudation was about doubled for at least two hours after the Dakin solution was removed. With flavine up to the time of its removal after

twenty-three hours there was a tendency to a diminution of the amount of exudate. Then, the yellow scum which is characteristic of flavine had formed, and after the flavine was removed, the exudate for at least two days was reduced to something less than half of what it had originally been.

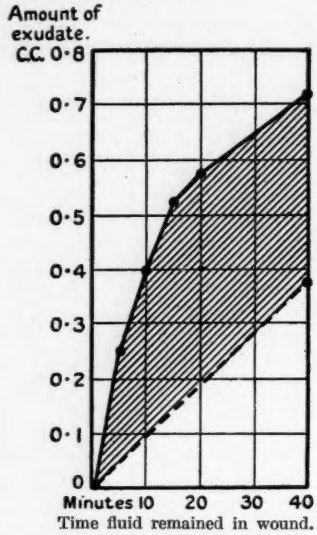


FIG. 134.—Rate of exudation of fluid into a wound cavity filled with 5 per cent salt solution. The continuous line represents the amount of exudate. The dotted line represents the amount of exudate into the empty cavity of the wound on the same day. ¶The shaded area indicates the amount of exudate which is actually due to the salt solution.

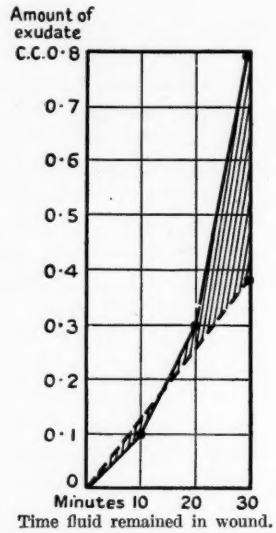


FIG. 135.—Rate of exudation into a wound filled with chloramine-T (4 per cent). Continuous line represents amount of exudate into cavity filled with chloramine-T. Dotted line represents amount of exudate into empty cavity on the same day. Shaded area indicates amount of exudate due to chloramine-T.

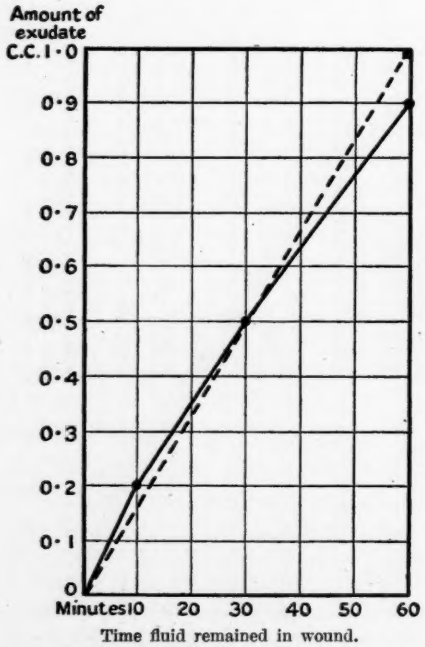


FIG. 136.—Rate of exudation into a wound filled with chloramine-T (1 per cent). Continuous line = exudate into cavity filled with chloramine-T. Dotted line = exudate into empty cavity on same day.

The rate of transudation into hypertonic salt solution is shown in *Fig.* 134. This should be read in conjunction with *Fig.* 130, and it will be seen that there is a very rapid outflow of fluid at first, but this falls off just as the strength of the salt solution diminishes. The shape of this exudation curve shows that the increase in the amount of fluid is directly due to the 'drawing' action of the salt, and not to an irritation of the walls of the wound, as there is no latent period, but when the salt is strongest the amount of exudate is greatest, and immediately the strength of the salt falls off the rate of flow diminishes.

This chart should be contrasted with *Fig.* 135, which shows the rate of exudation into 4 per cent chloramine-T. This concentration of chloramine-T was too strong for wound treatment, and when put into a wound it caused sufficient irritation to produce some capillary oozing after some minutes. Here it will be seen that there is no increase in the amount of exudate for twenty minutes, and then there is a very rapid outflow of fluid which is a reflection of the irritant action of the solution.

Chloramine-T in a 1 per cent solution had practically no influence on the exudation from the wound (*Fig.* 136).

Eusol, like chloramine-T in strong solution, at first shows a slight diminution in the amount of exudate, but this is followed by a very considerable increase (*Fig.* 137).

A consideration of *Fig.* 133 will show that Dakin's solution also has a mild irritant effect on the wound. This solution was only used in connection with the second of the wounds experimented on, from which there was normally only a small amount of exudate; but the rate of exudation into the fluid, and also into the empty cavity of the wound before and after the application of the fluid, is set forth in *Fig.* 138. It will be seen that at first the rate of exudation into the Dakin solution followed the same line as the exudation before the application; but it leaves this line, and in forty minutes has almost reached the line depicting the rate of exudation after the application. This is exactly what would be expected if the fluid exercised a mild irritant action.

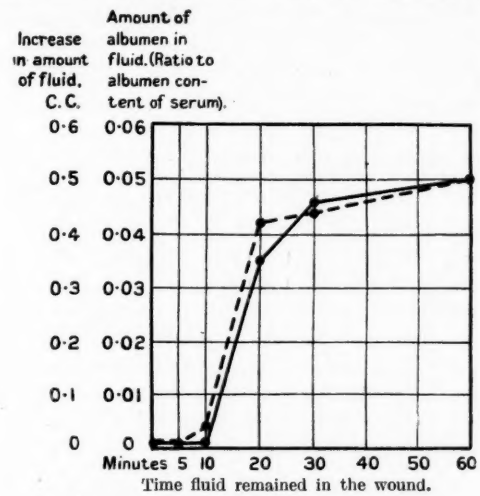


FIG. 137.—Rate of exudation of fluid (continuous line) and of albumin (dotted line) into a wound containing eusol.

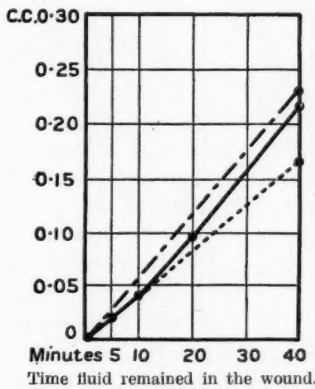


FIG. 138.—Rate of exudation of fluid into a wound cavity containing Dakin's solution, shown by the black line. The dotted line represents the exudate before application, and the thin interrupted line the exudate after application.

Amount of Albumin in the Exudate.—It has been asserted frequently that hypertonic salt solution, while it could by osmotic action attract water from the tissues, could not possibly attract albumins, as these are little subject to osmotic influences. I have measured the amount of albumin which was attracted into 5 per cent salt solution in a wound, and have compared this with the amount which passed out into normal salt solution. The results are seen in *Fig.* 139, from which it is clear that hypertonic salt solution draws an albuminous fluid from the tissues. This Sir Almroth Wright has always maintained, and has supported his contention by many *in vitro* experiments. Here his conclusions are absolutely confirmed by *in vivo* observations.

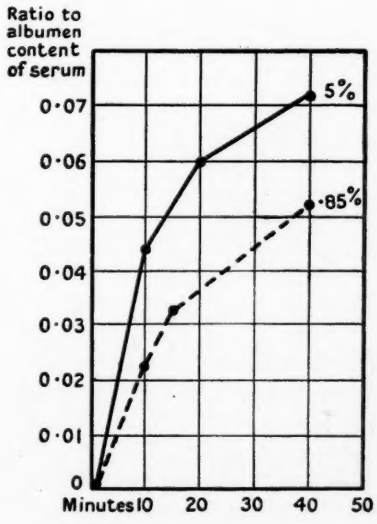


FIG. 139.—Amount of albumin in the exudate from a wound filled with normal and hypertonic salt solutions.

The amount of albumin put out into eusol is shown in *Fig.* 137, which shows that at first there is no albumin in the fluid; but after some twenty minutes there is a very rapid increase in the amount, and the curve follows very closely the curve of the amount of exudate. This is what would be expected if the increased flow is due to an irritation effect, as such an exudate would correspond merely to the ordinary inflammatory exudate. The same is true of chloramine-T.

Leucocytes in the Exudate.—The number of leucocytes varied very much in the two wounds on which observations were made, and we will deal chiefly with the findings in the first wound, which normally had a large flow of fluid containing many leucocytes (about one million per cm.).

Table IV.

Time during which Fluid remained in the Wound	Normal Salt	5 per cent Salt	Eusol	Chloramine-T 1 per cent
5 mins.	36,000	16,400	? *	? *
10 ,, ...	70,000	36,400	? *	? *
20 ,, ...	346,000	62,000	350,000	91,200
30 ,, ...	434,000	125,000	—	—
60 ,, ...	593,000	234,000	480,000	742,000

* Unable to count. Leucocytes broken up by chemical.

It will be seen from this table that all the non-physiological fluids introduced into the wound had a marked restraining effect on the emigration of the leucocytes. In the fluids, and particularly the hypochlorites, which were left in the wound for only five or ten minutes, accurate counts of the leucocytes could not be made, as the fluid had not lost its leucolytic power during the short time it had been in the wound. With 4 per cent chloramine-T no counts could be made, as the chemical had acted on the albumins with the formation of a glutinous mass. In connection with flavine (only tested in the second wound) the number of leucocytes fell from 4350 per c.mm. in the specimen of flavine which had been left in the wound for one hour to 850 per c.mm. in the specimen left in the wound for four hours. In the specimen left in the wound for fifteen and a half hours, it was impossible to count the leucocytes with even approximate accuracy, as by this time the wound had become covered with the characteristic membrane, portions of which came away with the fluid, and which, on microscopical examination, seemed to be composed chiefly of leucocytes in various stages of degeneration. In the exudate into the cavity for two days afterwards there were almost no leucocytes, apart from those contained in the membranous covering, which persisted for this time.

It will be seen that with the hypochlorite solutions tested (eusol and chloramine-T), the power of inhibition of the leucocytic emigration ceased in about twenty minutes, and after one hour the number of leucocytes in the exudate was almost as great with eusol as, and greater with chloramine-T than, it was with physiological salt solution. This is what would be expected when the rate is considered at which the active agent of these fluids is destroyed in the wound.

Bactericidal Action of Antiseptics tested in Vivo.—With normal and hypertonic salt solutions no bactericidal action was to be expected and no observations were made.

Chloramine-T 4 per cent.—To estimate the number of living microbes in the fluid removed from the wound after various intervals, 10 c.mm. of the fluid was plated in agar immediately after removal. The results obtained in this way with 4 per cent chloramine-T were as follows :—

Table V.

Time Chloramine-T remained in the Wound	No. of Colonies developing from 10 c.mm.
5 minutes	4
10 ,, ...	5
20 ,, ...	30 (surface overgrown with *B. proteus*)
30 ,, ...	79 ,, ,, ,, ,,
50 ,, ...	764 ,, ,, ,, ,,
Preliminary wash with normal salt	872 ,, ,, ,, ,,
Wash with normal salt immediately after the chloramine-T.	800 ,, ,, ,, ,,

We see from this table that even the specimen of chloramine-T which was removed after being in the wound for only five minutes (when the chloramine-T. was exercising its maximum bactericidal power) was not sterile. That the antiseptic had no real effect on the bacterial flora is shown by the fact that the wash with normal salt solution immediately after the application of the antiseptic gave, within the limits of experimental error, the same number of colonies as the wash with salt solution before the experiment started. It is to be remembered that here we are dealing with a solution of chloramine-T which is stronger than that used in the treatment of wounds, and which we have shown to be markedly irritant in the wound.

The microscopical appearance of the chloramine-T removed from the wound after remaining there for fifty minutes is shown in *Fig.* 140, from which it will be seen that it is very similar to ordinary pus, and a consideration of *Table V* will show that the microbes present in the pus were for the most part alive.

Dakin's Solution. — Ten c.mm. of the exudate before the application of Dakin's solution, and the same quantity of the exudate for one hour after the application of the fluid, were planted out in agar, and showed in the exudate 91 colonies before the experiment and 95 colonies after. In this experiment the Dakin's fluid was renewed four times during four and a half hours. This shows that the application of Dakin's solution to a clean wound without sloughs has no action in diminishing the number of microbes in the wound. If this solution really exercised a bactericidal effect in the wound, one would have expected some evidence of this in the above experiment, and if there is no bactericidal effect manifest when the fluid (renewed four times) has acted for four and a half hours, it is unlikely that there would be any bactericidal effect when the fluid is changed every two hours over several days, as in the Carrel method of treatment. Carrel has claimed that he has been able to sterilize wounds by means of repeated instillations of Dakin's solution, and he attributes to this solution great powers as an antiseptic. To accomplish this sterilization the solution is introduced into the wound every two hours for several days, so that in an average case there may be 60 to 144 instillations. We have seen that after five—or at a generous estimate ten—minutes, the strength of the Dakin solution falls below the point at which it is bactericidal in serum or pus, so that for one hour and fifty minutes out of every two hours there is no antiseptic in the wound. We have seen also that after, roughly, one irrigation with Dakin's solution per hour, the amount of the residual infection is unaltered. It seems inconceivable, therefore, that the Dakin fluid used after the method of Carrel can have any appreciable action as an antiseptic, and it seems reasonable, therefore, to assume that the benefit which Carrel derived from this solution was to be attributed, not to its bactericidal action, but to some other function

FIG. 140.—Microscopical appearance of fluid removed from a wound 60 minutes after being filled with chloramine-T (4 per cent).

which it performed in the wound, and not the least of its functions is its power of rapidly combining with the albumins in the wound and so disappearing as an active chemical agent.

Eusol.—Ten c.mm. volumes of eusol which had been allowed to remain in the wound for varying intervals were, as soon as they were removed from the wound, diluted 1000 times, and of this dilution 10 c.mm. volumes were planted in agar. The result was as follows :—

Table VI.

Time Fluid remained in the Wound	No. of Colonies Developing	Equal to No. of Colonies per c.c. of Original Fluid.
5 mins.	2	200,000
20 „	50	5,000,000
30 „	40	4,000,000
60 „	25	2,500,000

It will be seen that eusol was not capable of sterilizing the cavity of the wound, and that after a few minutes it apparently lost all its bactericidal power.

It is to be noted, also, that the maximum count of bacteria was obtained in the sample of eusol which had remained in the cavity of the wound for twenty minutes. It may be that this is due to the fact that although in the first few minutes the eusol may destroy some of the microbes, the leucocidal effect of the solution will persist for a longer time, so that in the twenty-minute sample the leucocytes have been put out of action for practically the whole period, while the bactericidal action of the solution was only effective for a few minutes. In the samples which had remained in the wound for longer periods, the diminution in the bacterial count might well be due to the activities of the leucocytes, no longer restrained by the action of the eusol, this having been completely dissipated.

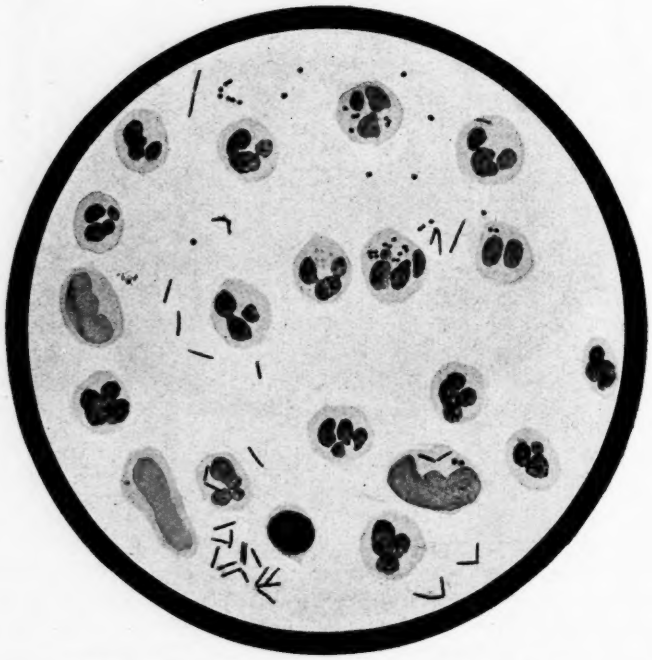


Fig. 141.—Microscopical appearance of fluid removed from a wound 20 minutes after being filled with eusol.

The microscopical appearance of the eusol removed from the wound after twenty minutes is shown in *Fig.* 141.

Flavine.—The number of living microbes in the wound after the application of flavine (1–1000) for a few hours could not be even approximately estimated, owing to the yellow membrane with which the wound had become covered by that time. Portions of this membrane came away in the fluid, and a satisfactory emulsion could not be made. The colonies, therefore, came up in clumps, and the number of colonies in each clump could not be estimated. It appeared, however, that the number of living microbes in the fluid

increased the longer the flavine had remained in the wound, up to fifteen and a half hours, which was the longest time during which observations were made.

Effect of Fluids introduced into the Wound on the Antitryptic Power of the Exudate.—The results obtained in this connection are set forth in *Fig.* 142. It will be seen that hypertonic salt solution reduces the antitryptic power of the exudate slightly for a short time after its application. With eusol the reduction is very marked, but after about forty minutes the exudate had returned to normal. With the Dakin solution applied for four and a half hours the reduction was very marked, and persisted for at least two hours. Flavine had no effect on the antitryptic power.

The effect of this reduction of the antitryptic power is twofold. In the first place, as has been shown by Sir Almroth Wright, this reduction will favour the growth of all the microbes in the wound (*Fig.* 111); and in the second place it will remove the chief obstacle to the tryptic digestion of sloughs. The former would seem, on the face of it, to be a bad effect, whereas the second can only be favourable. A balance must be struck between these two actions, and in different stages of the wound they will have different relative importance. In the early stage, when there are many sloughs on the surface, there is practically always a mixed flora, and the discharge is usually either tryptic or possesses very little antitryptic power. In such a case, therefore, little harm is going to result in a further reduction of the antitryptic power, and the all-important thing in such a condition is to get rid of the sloughs. We see, then, that the hypochlorite solutions, eusol and Dakin's solution, by reducing the antitryptic power of the discharges will favour the tryptic digestion of the sloughs; but another thing to be remembered is that these solutions have some destructive action on the tryptic ferments. We are confronted, therefore, in connection with these solutions with a destructive effect on trypsin and also a very great reduction in the antitryptic content of the discharges. The effect on trypsin, however, is not a very marked one, and it is very possible that the reputation which Dakin's solution has acquired for cleansing a wound of sloughs is due chiefly to its powerful action in the reduction of the antitryptic power of the exudate.

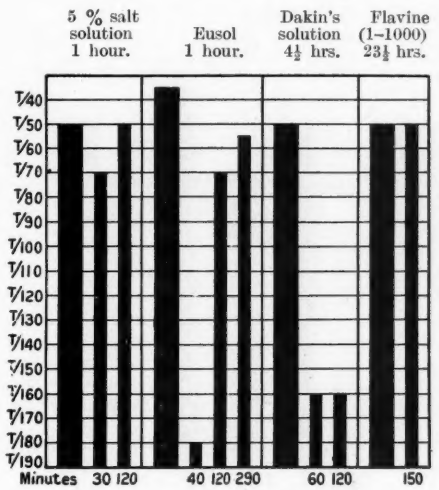


FIG. 142.—Antitryptic power of the exudate into a wound cavity before and after the application of salt solution, eusol, Dakin's solution, and flavine.

Thick columns = antitryptic power of exudate before application.
Thin columns = antitryptic power of exudate after application.
The times recorded show the interval which had elapsed between the removal of the test fluid and the withdrawal of the exudate.

It is true that Dakin's solution has a very marked effect in dissolving cells; for instance, if an emulsion of liver cells be put into Dakin's solution, they are completely dissolved in a few minutes; but this solvent effect is not so evident when connective tissue is placed in the solution. Sloughs are adherent in the wound by virtue of connective tissue, so the direct solvent action of Dakin's solution would have little effect in the separation of these, and it is much more likely that they are separated by a process of auto-digestion. So far as I have seen, there is no application which removes sloughs from a wound so quickly as hypertonic salt solution, and we can see that this may well be so, as this solution has no destructive effect on the tryptic ferments, as has Dakin's solution.

Following from the experiments cited above, we see that none of the so-called antiseptics which are commonly used in wounds are capable of exercising any appreciable bactericidal action in an infected wound. We have seen that they are incapable of sterilizing a glass tube with one or two processes much smaller than the diverticula to be found

in a gunshot wound. Much less would they have any sterilizing action on a wound with infected walls (as all wounds have when the infection has become established). We have seen also that when put into a comparatively clean wound they have no sterilizing action. Also, that when a perfectly clean flat granulating wound without diverticula is washed with these antiseptics and impression cultures are made before and after the application, there is no reduction in the number of microbes which develop in the cultures, but, on the other hand, there is usually an increase in the number of colonies owing to the destruction or removal of the chief natural means of defence, namely, the leucocytes.

It is very noteworthy that the antiseptic which has the most marked inhibitory power on the growth of microbes in a serous fluid should have been found unsuitable for the continued treatment of a wound. Of all the antiseptics in common use there can be no doubt that flavine exercises the most powerful inhibitory action on the growth of microbes in serous fluids ; yet it has been generally found in France that this fluid was not suited for the continued treatment of an infected wound. This is, in all probability, due to its very strong and continued action in destroying the leucocytes in the wound. It was introduced partly because it was supposed to be innocuous or almost innocuous to leucocytes ; but I have shown elsewhere that it is a slow-acting but extremely powerful leucocidal

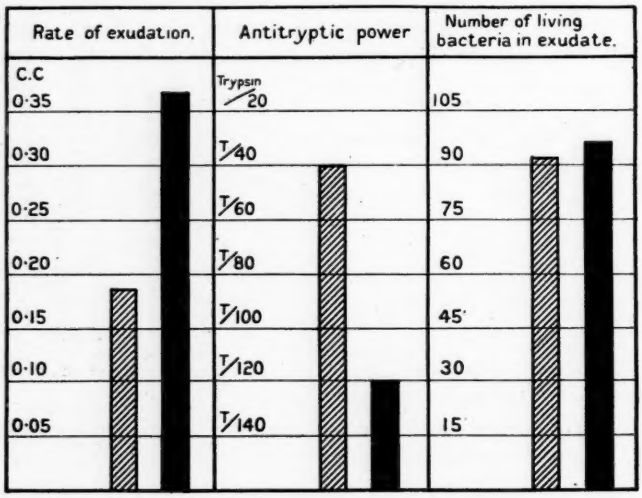


FIG. 143.—Effect of Dakin's solution applied to a wound for 4½ hours in four changes. Shaded column = exudate before application. Black column = exudate after application.

agent, destroying them in twenty-four hours in as great a dilution as 1–2,000,000. The result of this seems to have been that all reparative processes in the wound come to a standstill.

Eusol and Dakin's solution, on the other hand, have found very many supporters in the treatment of wounds in which the infection has become established. We have seen that when these are put into a wound the active agent disappears in a few minutes, after which the natural defensive mechanism can proceed unhindered. These solutions also cause a mild irritation in the wound, which results in a greatly increased flow of lymph from the tissues, thus imitating the tissue-draining character of hypertonic salt solution. The exudate, after the application of these fluids, also has a very low antitryptic content, thus favouring the tryptic digestion of the sloughs. The bactericidal action of these solutions in a septic wound appears to be negligible. *Fig.* 143 illustrates graphically the results of the application of Dakin's solution to a wound, so far as they could be tested. It will be seen from this that whilst as regards the amount and the antitryptic power of the exudation there were marked changes, yet as regards the number of bacteria in the exudate before and after the application of the fluid there was no change. In view of

this, it is not unreasonable to assume that the benefit which the wound derived from the application of Dakin's solution was due, not to its bactericidal action, but to its stimulation of the physiological processes occurring in the wound.

The only other agent which has obtained any great measure of support in the later treatment of infected wounds has been Rutherford Morison's B.I.P.P. This is not in itself a bactericidal substance, and in contact with tissues or tissue fluids we have never been able to demonstrate that it has any bactericidal action ; but just as it has no bactericidal action, so it has no toxic or repellant action on the leucocytes, and it can easily be demonstrated that these will emigrate in large numbers on to a surface to which B.I.P.P. has been applied. We have seen (*Fig.* 124) that when a wound is washed with a solution of the common antiseptics, the number of colonies which develop in an impression culture is greater after the washing than before. Rutherford Morison has always insisted that after surgical treatment of the wound and the application of B.I.P.P. the wound should not be touched for a considerable time, and it is possible that much of the success of this treatment has been due to leaving the wound alone. The actual infection would be dealt with by the leucocytes. It is possible also that the greasy nature of the application prevents the shutting up of the discharges which would take place in a wound left alone after treatment with a watery fluid. If this were so, then pastes containing substances less poisonous than bismuth and iodoform would give equally good results, and certain reports seem to show that this is the case.

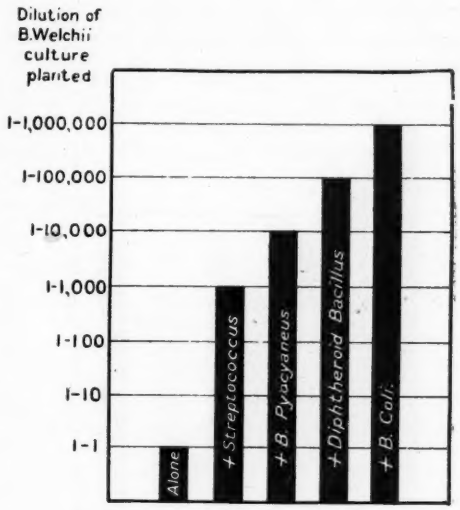


FIG. 144.—Influence of the presence of other bacteria on the growth of *B. Welchii* in serum. Columns represent the dilutions in which growth of *B. Welchii* occurred.

In view of the observations I have made, and which are quoted above, I venture to suggest *that the antiseptics at present in use will only exercise a beneficial effect in a septic wound if they possess the property of stimulating or conserving the natural defensive mechanism of the body against infection.*

If such a thesis be true, then it brings the 'antiseptic' and the 'physiological' treatments on to the same basis, and it also makes it necessary, in the estimation of the value of an antiseptic, to study its effect on the tissues more than its effect on the bacteria.

ANTISEPTICS IN PROPHYLACTIC TREATMENT OF WOUNDS.

Up to the present we have been dealing with the treatment of a wound in which the infection has become established ; but even more important is the prevention of infection in the treatment of war wounds, and it is here that antiseptics find their true application. It has often been said that these war wounds contain already so many microbes that it is little use taking extreme precautions regarding their treatment, as a few microbes more or less will make no difference. In *Fig.* 144 I have shown graphically the effect which certain microbes have in stimulating the growth of *B. Welchii*, and we have shown that almost all the microbes which constitute the primary infection of the wound, or which are put in later by the surgeon or the sister, have a mutually beneficial symbiotic action. It follows from this that even where the wound is apparently badly infected, the same care should be exercised in the dressing as would be taken if the wound were a sterile one. It has been shown[4] that *Streptococcus pyogenes*, which is responsible for most of the severe sepsis in the later stages, and causes more deaths from sepsis than all the others put

together, is present in only 15 per cent of the wounds when they arrive at the clearing stations.

I have found that this organism is present in about 20 per cent of cases when they arrive at the base when they have been sent on immediately after excision and packing of the wound. After they have been at a base hospital, however, for more than a week, *Streptococcus pyogenes* is present in almost all the wounds (I speak here only of wounds which have not been sutured but which have been repeatedly dressed). It would appear, therefore, that faulty technique in dressing the wounds was responsible for the almost universal presence of this, the most dangerous of all the microbes found in the wound. The only way to avoid this spread of infection is by the most careful technique in dressing and by the lavish use of antiseptics *outside* the wound. All these antiseptic solutions are powerful bactericidal agents in a watery medium, and outside the body the strength can be increased, as no question of damage to the tissues comes in here. In civil hospitals the equipment is such that sterilization by heat has largely displaced sterilization by antiseptics, but in military hospitals in the field the equipment is, of necessity, more primitive, and there sterility can only be obtained by the lavish use of chemical antiseptics.

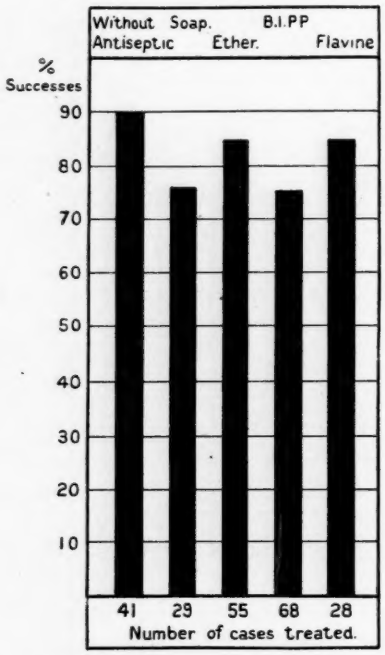


Fig. 145.—Results of wound treatment by various agents.

In connection with the prophylaxis of infection, we have the question of the early treatment of the wound before the infection has had time to grow out and while it is confined to the cavity of the wound. There is no question about the efficacy of early and thorough surgical treatment; that has proved its value without a doubt. There has been controversy, however, regarding the value or otherwise of chemical agents as adjuncts to this surgical cleansing. An experiment was carried out about a year ago at No. 10 Casualty Clearing Station in which primary suture was done on wounds excised and treated with various agents. The results obtained are shown in graphic form in *Fig.* 145, from which it will be seen that there is no great difference between the number of successes whatever the method of treatment. It is true that the largest percentage of successes was in the group sewn up without the application of any antiseptic; but this is explained away by saying that in most cases the surgeon only dared to sew up wounds in this way when they were not very serious. It has been found in several large series of delayed primary sutures that the results were practically identical whether the wound had been packed with gauze soaked in an antiseptic, or whether plain gauze had been used as the primary dressing after excision of the wound at the casualty clearing station.

During last summer I examined the packs removed from 75 cases of fractured femur on arrival of the patients at the base. These packs were mostly soaked in flavine, but there were also a certain number of B.I.P.P. or plain gauze packs. In all cases I found microbes present, and there seemed to be little difference between the bacterial content of the different varieties of pack. This observation, taken into consideration with the results of delayed primary suture at the base and with primary suture at the front, would seem to show that the antiseptic plays no part in the primary treatment of a wound.

If this is so, then there is a very great disadvantage in the use of an antiseptic from the surgeon's point of view. It is very difficult for the surgeon not to be deluded into the belief that he has in the antiseptic a second string to his bow, and consequently it will tend to make him less careful in his surgical treatment of the wound. If he knows that he has

nothing to fall back on, then, even with the most conscientious individuals, the surgery would improve. Because of this alone it would be well if the treatment of the *wound* with antiseptics in the early stage were abandoned and the surgeon relied on his skill alone. All the great successes of primary wound treatment have been due to efficient surgery, and it seems a pity that the surgeon should wish to share his glory with a chemical antiseptic of more than doubtful utility.

Many of the experiments quoted above were the results of 'team' work, and I do not wish to close without thanking my chief, Sir Almroth Wright, and my colleagues at St. Mary's Hospital and at No. 13 General Hospital, especially Captains Douglas and Colebrook, for permission to use work in which they took a share.

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ACUTE NECROTIC PAROTITIS.

By V. ZACHARY COPE, London.

Prior to a sojourn in Mesopotamia, the most acute form of parotitis that I had seen was of the suppurative type, which occasionally gave rise to severe symptoms, but seldom imperilled life, and generally subsided under appropriate treatment without any necrosis of the gland. Whilst working in Baghdad during the extremely hot summer of 1917, I encountered several cases of a more severe nature than I had previously seen, nor do I remember in general surgical literature any account of such a severe type of parotitis. The condition to which I am now calling attention is an acute necrosis of the parotid gland, and the name *acute necrotic parotitis* or *acute gangrenous parotitis* would serve well to distinguish it from the less severe suppurative forms.

Etiology.—Whilst bacterial infection with staphylococci or streptococci was always the immediate exciting agent, yet the more important element in causation was the predisposition induced by excessive heat or debilitating diseases. All the seven cases which I had under my care occurred in 1917; five of the seven came for treatment during the excessively hot months of July and August, when 120° was a common shade temperature. I had intended to take special notes of any cases that might occur in 1918, but the summer of that year was cooler, and did not cause the thermometer to register more than 117° at any time; thus my opinion that the excessive heat was the chief predisposing factor was borne out by the fact that not a single case came under my observation in that year.

Several of the patients had either suffered from a heat-stroke or had been affected severely by the heat; and only those who have seen them can fully realize the extreme effects of high temperature on the body resistance.

The malarial parasite was not found in the blood of any of the three patients who were examined specially for that purpose. One patient was in a weak state as the result of dysentery, and was found at autopsy to have pus in the gall-bladder.

The invasion of the parotid by septic organisms travelling along Stenson's duct is the most likely mode of infection, though a pyæmic origin from some small septic focus elsewhere must be admitted as a possibility. Though the mouth was seldom dirty, it was as a rule drier than usual, as would be expected during such extreme heat. Streptococci and staphylococci were the only organisms recovered from the necrotic glands.

Pathology.—The parotid is covered by a dense capsule of fibrous tissue, and its deep relations present a firm bed which allows of little expansion. There is therefore little occasion for surprise that a virulent infection should cause such an increase of tension as to lead to gangrene. At the same time the important factor is that which exalts the virulence of the microbe or depresses the vitality of the tissues—else we should expect a much more frequent occurrence of necrosis.

The whole gland may become gangrenous, and both glands may be involved in the same patient. After incision, small or big sloughs come away for some days, and when the dead tissue has all escaped, the anatomical structures on the deep aspect of the parotid are exposed as if by dissection. The thrombosed temporomaxillary vein will be seen crossing the space, the external carotid artery will be felt pulsating, and the styloid process will easily be palpated at the bottom of the wound. If the gland be incised during the early stage of the inflammation, little or no discharge will come away from the gangrenous tissue; but later, as the sloughs separate, a copious purulent discharge escapes. If the gland be not incised early enough, the discharge finds for itself the weak spot in the capsule of the parotid, and bursts into the external auditory meatus at the junction of the bony and cartilaginous portions.

The size of the sloughs which come away is variable, but on opening up the wound in one case I removed a loose slough measuring $1\frac{3}{4}$ in. by $1\frac{1}{2}$ in. by $\frac{1}{2}$ in.

Clinical Course.—The usual course of the disease was as follows. A man who had been for some time in a debilitated condition, or who had been weakened by suffering from the effects of heat or even a true heat-stroke, would develop a swelling in the parotid region, accompanied by fever and general symptoms of malaise; after a few days an incision would be made into the swellings, but usually no improvement took place, since the initial incisions were always too small. By the time the cases came under my care they had often already received several insufficient incisions, and it was forced upon me that the only satisfactory treatment was incision on a much freer scale. If the gland was very freely incised, recovery usually followed after the substance of the gland had come away by sloughing. In cases of severe toxæmic type, unless incisions were freely made, or if they were not made early enough, death resulted from septic absorption.

The fever was irregular, being usually about 102° until sufficient drainage was secured. In the two fatal cases a temperature of 104° was reached on several days.

After the sloughing away of the gland, the wound granulated up slowly or quickly according to the vitality of the patient. In spite of the free incisions made, I did not see any evidence of facial palsy develop, though it is possible that the scar tissue will eventually affect some of the branches. Most of the cases left my care before the wound was quite healed.

Treatment.—In the early stages of the condition it is impossible to say how serious the pathological process will be, and the usual treatment will be fomentations applied to the part. But when once the condition is seen to be of a serious nature, it is necessary to take prompt surgical measures. These consist in making free incisions into the affected gland at the earliest opportunity. By this means the tension inside the gland is relieved, absorption of the toxic products is prevented, the dead gland material is allowed to come away, and possibly the gangrene may be limited in extent. At the same time pain is relieved. I do not remember to have seen described any efficient way of draining the parotid gland, and it was only by rather bitter experience that I learnt a satisfactory method.

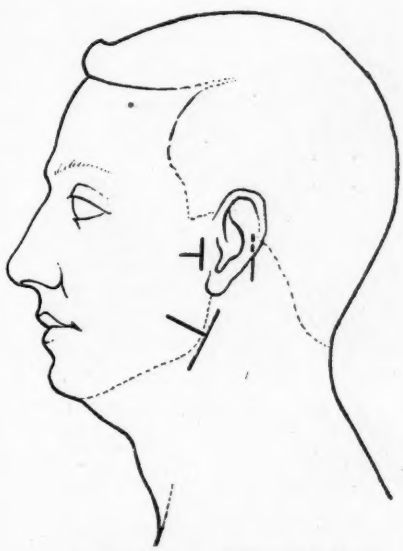

FIG. 146.—To show the incisions which allow of free drainage of the parotid gland.

The usual method recommended for opening a parotid abscess is by Hilton's procedure, using a small incision, with director and sinus-forceps. For the gangrenous forms it is always futile, and often fatal, to make a small incision or to attempt Hilton's method. I never regretted opening up freely, but on two occasions I had to lament that I had not done so freely enough. In planning the incisions, one must remember that the main mass of the gland swelling is around the angle of the jaw, and that separate openings are needed for the upper part of the gland and for the portion which lies against the mastoid process. The incisions which I have found useful consisted of a large ⊥-shaped cut at the angle of the jaw over the maximum swelling, a subsidiary incision —straight or ⊥-shaped—in front of the auricle, and a straight cut behind the auricle over the mastoid process (*Fig.* 146). If the mastoid incision were not made at first it was always needed later. Through these incisions the gland can be thoroughly explored and opened up, and, if thought fit, rubber drainage-tubes can be inserted to prevent the deep parts from closing together and thus preventing drainage. The necrotic gland substance bleeds very little, but occasionally vessels in the surrounding tissues need

ligature. The first time I used the large ⊥-shaped incision was on the advice of Colonel Legg, A.M.S., and I found it so efficient that I adopted it in later cases.

The after-treatment of the wound consists in applying fomentations and dressing frequently until the sloughs have come away, and then using antiseptic dressings until healthy granulations appear.

Since the patients are usually debilitated, it is advisable to administer tonics and hæmatinics—always remembering that nourishing and easily digestible food is the best of both. Patients with inflamed parotids must have liquid or soft food.

Seven cases came under my care; three ended fatally, but one of the deaths was attributable to other causes than the parotid condition.

Case 1.—J. W., age 26. First felt poorly July 10, 1917. Had headache and backache. Diagnosed first as sand-fly fever, then as 'effects of heat.' Admitted to hospital on July 17. General condition fair, but acute swelling of parotid supervened. July 25.—Anæsthetic given and parotid gland incised. Condition became worse, with high fever and delirium. Blood examination was negative as regards malaria. Patient died of acute toxæmia on July 30. In this case the incision was comparatively small, and not as deep as later experience showed to be necessary.

FIG. 147.—Photograph of *Case* 3 to show granulating wounds after the free incisions recommended by the writer. The ridge formed by the temporomaxillary vein can be seen.

Case 2.—T. J. W., age 30. Feverish for ten days prior to admission. The heat had affected him badly, and he was treated for debility on admission to hospital on July 10, 1917. Acute inflammation of the left parotid developed. July 16.—Parotid gland incised under local anæsthetic. July 19.—Free incision under gas anæsthesia. At first very little discharge came away, but later it increased. Four incisions were made, two over posterior and lower border of lower jaw, one over mastoid, and one lower down in the neck. After-course was uneventful and satisfactory.

Case 3.—S., age 29. Admitted July 24, 1917. History of exposure to the sun. Temp. 100°, pulse 94. Complained of pains in head, back, and chest. Constipated. No abdominal symptoms. Blood-films negative to malaria. July 26.—Symptoms of left-sided parotitis. July 29.—Parotid incised. Patient very cyanosed, as were several of the severe cases. July 31.—Free incisions were made, and the whole gland found to be necrotic. Aug. 3.—Much better. Œdema of eyelid disappeared. Aug. 15.—Sloughs separated. Posterior division of temporomaxillary vein exposed in the wound (*Fig.* 147). Patient evacuated soon after.

Case 4.—W. T., age 34. Admitted July 21, 1917, with symptoms of heat-stroke. July 28.—Transferred to the surgical ward. There was great swelling of right side of face, and some œdema of left side. Under an anæsthetic an oblique incision was made into the mass opposite the angle of the jaw, and sinus forceps were passed into the parotid gland. No improvement occurred. Discharge was extracted, but the swelling continued. Patient became incontinent and had dysphagia, and finally became unconscious. July 31.—Under general anæsthetic very free incisions were made into right parotid and surrounding tissues. Gland was found necrotic. Carotid artery felt at bottom of wound. In addition to blood lost at operation, patient was bled 6 ounces. After the operation, swelling subsided, but general condition remained serious. Saline given per rectum. Camphor and brandy exhibited. Aug. 1.—Ashy-grey pinched appearance. Unconscious and incontinent. Saline, 2 pints intravenously. Evening temperature 105°. Saline, 2 pints intravenously. Aug. 2.—A little better. Conscious and continent of urine. Sloughs coming away freely. Eusol dressings four-hourly. Aug. 3.—Weaker; temp. 104°. Pleuritic rub detected. Dose of ten million streptococcus vaccine given. Blood negative to malaria. Patient died two days later.

Case 5.—J. B., age 35. Admitted Sept. 20, 1917, for dysentery and abdominal pain. Fever intermitted between 103° and 98°. Sept. 25.—No redness. Left side of neck painful and swollen anterior to sternomastoid, where there was more tenderness than over parotid. Swelling hard and brawny. No fluctuation. Sept. 29.—Swelling greater, skin red. General anæsthetic given. ⊥-shaped incision made across angle of jaw. Counter-operation in pre-auricular region. Necrotic parotid gland, with some thick flaky pus. Oct. 1 to 9.—Parotid condition improved, but general

condition became worse, and death occurred on Oct. 13. At autopsy, the colon was found ulcerated, there was an empyema of the gall-bladder, and three infarcts were found in the spleen.

Case 6.—F. C. P., age 24. Bilateral acute necrotic parotitis. Two or three weeks before, patient had 'hot and cold shivers,' which lasted about a week. There was at this time no pain or swelling of the face. Was isolated as a small-pox contact. During this time both sides of his face swelled and became painful. Small incisions had been made on both sides before he was admitted to hospital. Nov. 29.—On admission. Great swelling of face both sides. Temperature 96° (axilla). Pulse 88. Severe anæmia. Incisions about one inch in length had been made below and behind the auricle on both sides, and there was free discharge of pus. Pain not severe. Dec. 1.—Operation under general anæsthesia. Both parotid glands thoroughly opened up by cruciform incisions, with centre just behind and below angle of jaw. On both sides there was found an almost complete necrosis of the parotid gland, which readily came away in a sloughing condition. On left side one slough measured $1\frac{3}{4}$ by $1\frac{1}{2}$ by $\frac{1}{2}$ in., and was quite loose in depth of wound. When the necrotic material had been removed, the styloid and mastoid processes lay almost bare, whilst the thrombosed temporomaxillary vein and its junction with the posterior auricular vein were exposed in the wound on both sides. The right external carotid artery was felt pulsating deep in the wound. Wound was packed. Bismuth-iodoform paste used as dressing on the right side, and eusol on the left. Pus reported to contain staphylococci. Dec. 10.—Wounds healing rapidly. Dec. 26.—Almost healed on right side. Healing well on left side. Patient evacuated.

Case 7.—Unfortunately I have no notes of this case of necrotic parotitis except that two operations were necessary on Aug. 12 and 15, 1917. Recovery took place.

CONCLUSIONS.

1. There is an acute inflammatory infection of the parotid to which the term acute necrotic parotitis is applicable.

2. The condition may be bilateral or unilateral.

3. The predisposing causes are debilitating conditions such as severe effects of heat, dysentery, or other severe illness. The exciting cause is infection with septic organisms.

4. The condition leads to severe general toxæmic symptoms which result fatally unless there is prompt surgical intervention.

5. Treatment by very free incision and drainage of the affected parotid gland is imperative.

SHORT NOTES OF RARE OR OBSCURE CASES.

AN UNUSUAL CASE OF INFLAMMATION OF THE TRANSVERSE COLON AND MESOCOLON: PROBABLY ACUTE SIGMOIDITIS.

By A. E. MORTIMER WOOLF, London.

The patient, a soldier, age 29, was admitted into the Station Hospital, Kasauli, India, on June 14, 1918, at 9.0 p.m. He had been sent from Solon, a distance of about fifteen miles. Three days previously, at mid-day, he had been seized suddenly with abdominal pain. The pain was very severe all over the abdomen, but after a few hours it lessened in intensity and became localized to the right side. On the third day after the onset he vomited, the pain increased, and he reported sick. No history could be obtained of any previous attack. He was immediately transferred to Kasauli as a case of acute appendicitis.

The patient was seen shortly after admission, and then appeared exceedingly ill. The temperature was 103°, pulse 116. The abdomen was distended, and did not move on respiration. General rigidity and tenderness were present, and were especially well marked on the right side. Vomiting had been frequent during the journey.

It was decided to operate immediately Under the anæsthetic a distinct swelling was felt below the right costal margin. The peritoneum was opened through the right linea semilunaris, and the swelling was then seen to consist of a mass of indurated inflamed transverse mesocolon and transverse colon situated about two inches from the hepatic flexure. The affected area in the intestine was at the attached border and did not extend all round the circumference of the gut. The mass was adherent to the right lobe of the liver, which was enlarged ; a distinct lobe, comparable to a Riedel's lobe, presented where the adhesion occurred. The affected area in the transverse mesocolon was fan-shaped, with the apex at the attached border of the intestine. The inflammatory process had clearly started in the intestine and spread backwards between the two layers of peritoneum.

The mass was separated from the liver, but no cause was found for the condition. The appendix was healthy and the mesenteric vessels were normal. Nothing abnormal was found in the gall-bladder or bile-ducts. The portion of liver to which the mass was adherent was necrotic. A small piece was excised for subsequent microscopical examination. The liver was punctured in various directions, but no abscess was discovered. A large tube was inserted between the liver and the inflamed mass, and the wound closed. Two days later there was a copious discharge of pus, and from that time convalescence was uneventful. The pus contained staphylococci and bacillus coli, but no amœbæ. The section of liver tissue showed a round-cell infiltration.

The diagnosis of this case has been made by a process of exclusion. No cause for the inflammation could be discovered ; but the distribution of the inflammatory area, which was quite localized, strongly suggested that the inflammation had started in the attached portion of the intestine and had spread into the transverse mesocolon. No hernia of the intestinal mucous membrane was seen, but the intestine was not examined from the internal aspect.

The inflammatory distribution agrees closely with the observations of Beer,[1] Erdman,[2] and others, who have described the condition of diverticulitis. This case appears to have been an early one, with the acute symptoms as a first sign. Diverticula are usually multiple, and occur in patients over 35 years old. They may, however, be single (Stengel[3]), and Erdman[2] has reported seven cases under 35, Ashurst[4] one at 7 years. I have been unable to find a recorded case of diverticulitis in the transverse colon, but Kemp[5] mentions its occurrence in the small intestine. It is, however, difficult to understand why, in this case, there should have been any congenital or acquired weakness of the intestinal muscular wall at this particular spot, which must be presupposed if Beer's view of the causation of diverticula is the correct one. The patient was young, healthy, and under 35 years. There was no history of previous constipation ; no other cause of pressure from within could be discovered.

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[2] Erdman, *New York Med. Jour.*, 1914, March 14.
[3] Stengel, *Text-book of Pathology*, p. 573.
[4] Ashurst, quoted by Erdman (*vide supra*).
[5] Kemp, *Diseases of Stomach, Intestines, and Pancreas*, p. 843.

A CASE OF MYOSITIS OSSIFICANS TRAUMATICA, PRESENTING TWO ISOLATED PATCHES OF OSSIFICATION IN THE QUADRICEPS, THE RESULT OF TWO SEPARATE TRAUMATA.

By Captain GEOFFREY JEFFERSON, R.A.M.C. (T.C.)

The following case presents some interesting features, and in so far as there are two distinct and separate patches of ossification in the quadriceps extensor femoris, the result of traumata received on different occasions, the type is one of extreme rarity. One of the patches was fixed to the upper end of the patella. Liberation of osteoblasts from this bone as a result of injury is very unusual, no doubt owing to the manner in which its periosteum is reinforced and laced by the extensor tendon of the thigh.

The clinical history is as follows :—

Driver W. M., R.F.A., age 20, was kicked by a horse on the front of the left thigh on May 23, 1918. A considerable swelling developed, with accompanying stiffness of the limb. He continued his duties for a full month, hoping the disability would wear off. As time brought no improvement he was sent into a field ambulance, and there, with rest, the stiffness grew less and the range of movement in the knee considerably increased. The patient insists—and this is important—that the knee-joint itself was, up to that time, quite normal. The limitation of movement was doubtless due to the ossification

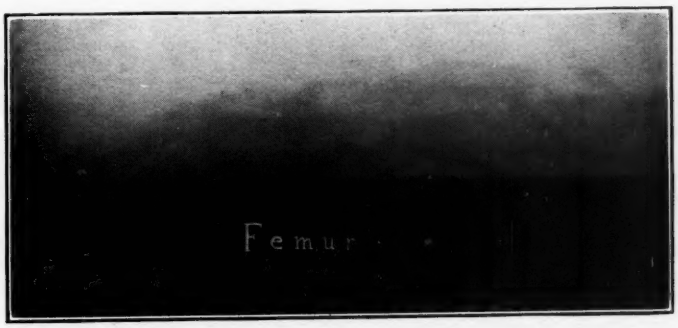

Fig. 148.—Diffuse ossification deep in the quadriceps at the middle of the thigh. Lateral view.

which was going on in the quadriceps binding that muscle to the femur. He returned to duty after eleven days, but on July 9, 1918, whilst leading two horses over some slippery ground, he fell heavily on the point of the left knee, which very quickly swelled up. After this accident he could hardly walk, and was sent down to the base. He was admitted into No. 14 General Hospital July 11, two days after the second accident and six weeks after the first. A swelling of bony hardness was then noted deep in the extensor muscles at the middle of the left thigh. The knee-joint was considerably swollen, but there was little fluid in it. Treatment consisted in Scott's dressing, back splint, and bandage. A week later there was no diminution in the size of the knee, so puncture was performed under novocain. The results of this puncture were puzzling at the moment, for only a small quantity of yellowish fluid was recovered, and the needle point engaged in a gritty substance that felt like a mixture of powdered bone and plasticine. The leg was *x*-rayed by Captain Dale, and two shadows were seen in the quadriceps; the one at the middle of the thigh was a characteristic intramuscular ossification (*Fig.* 148), the second was a faint sickle-shaped shadow at the top of the patella (*Fig.* 149).

July 27.—An exploratory arthrotomy was performed with a view to ascertaining the exact nature of the condition. A flat plaque of bone of circular shape some four centimetres in diameter was found to be lying in the deep substance of the tendon of the rectus femoris, and was quite immovable apart from this rigid structure. At its lower end it just reached the top of the patella. A small portion was removed for microscopy; it was quite soft and evidently very young. The synovial membrane was thick and dark brownish-red in colour, as if from old hæmorrhage. An Esmarch's bandage had been applied prior to the incision, so this colour was not due to hyperæmia. The ossification in the thigh was not touched. Convalescence was smooth, and the patient was allowed up on the tenth day, massage being begun shortly after. He was kept under observation for another two weeks. On discharge to England the knee had loosened up considerably, and he could bend it through some 65 degrees. The joint was still generally swollen.

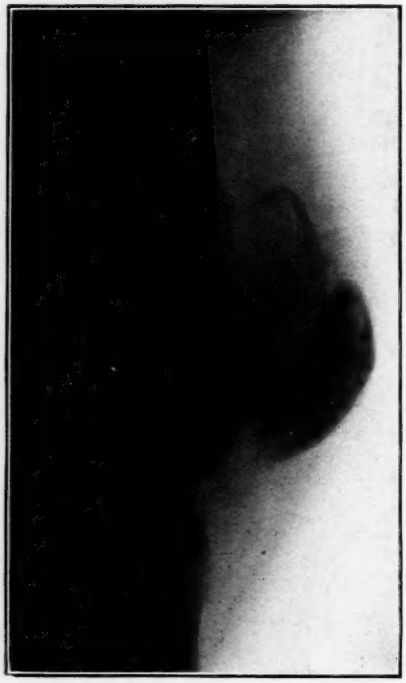

FIG. 149.—Area of ossification in the deep surface of the quadriceps tendon. It springs from the upper end of the patella, and is superficial to the synovial membrane. The patella is curiously tilted backwards.

The lower patellar bone plaque was never discernible on palpation, the other was very obvious. The operation explained the peculiar shape of the lower shadow as seen on the *x*-ray plate (*Fig.* 149). One is looking at a disc of unequal density from the side, and as the photograph is not a true lateral of this disc it presents as an ovoid.

When heard of through the Medical Research Committee three months later, the leg was greatly improved and the knee-joint movements were free. Unfortunately the small piece of bone was lost in transit to England.

It may be urged that the time which had elapsed between the second injury and the discovery of the bone plaque was too short for the bone formation to have been the result of that injury. These intramuscular ossifications are, however, extraordinarily rapid in their development, as most writers have noted, and the clinical observation is fully borne out by the animal experiments of Berthier, who found bone and cartilage formed within a week of an experimental injury.

Cases in which two distinct areas of ossification have resulted from two distinct

traumata are very uncommon. I have been able to find, in the now very voluminous literature of myositis ossificans, only one similar case, one of Berndt's.

Injury to front of left thigh by shaft of waggon: six weeks later Berndt removed a large osteoma which sprang from femur and invaded the quadriceps.

Two and a half years later, patient was kicked by a horse on thigh above the site of former injury, and Berndt again removed an intramuscular ossification. There was no connection with old scar, which was quite sound, and the bone was smooth at site of previous accident.

My own patient is quite sure that the knee itself was all right until the second accident. There is therefore little doubt that the statement that the two foci of ossification were the result of two separate and individual injuries is correct. This is important, because cases are on record where a single trauma has produced more than one patch of ossification. Such are :—

Busse and Blecher.—Kick on front of thigh by horse, swelling 14 cms. above the patella. Operation six weeks later; one osteoma removed from the quadriceps, a second found just above the knee, but not removed for fear of opening joint. Recurrence; whole of lower third of femur was thickened, but knee movements were good.

Sieur.—Man strained his thigh, riding. At operation, four bone nodules were found in the adductor longus, quite separated from one another. Removed. The same author records two other cases of a somewhat similar type.

Juxtapatellar ossifications, such as my own and Busse and Blecher's, are very uncommon. I have been able to find only two other cases.

Loison.—Patient fell whilst running; knee rapidly swelled. Fell again two-and-a-half months later, and felt something crack at top of patella. A radiograph showed a juxtapatellar osteoma, which progressively increased in size. Movements of knee were good finally, as in my case.

Lejars.—This was an infrapatellar ossification. Lejars removed a large osteoma from the substance of the ligamentum patellæ. There is no note of a recent injury here.

The pathology of the majority of these intramuscular ossifications is well discussed by Strauss and Delorme, and has been set on a firm basis by Morley, and his work fully explains the patch on the front of the thigh. I should like to draw attention to a beautiful series of radiographs by Stone, which excellently illustrate Morley's contention.

The juxtapatellar ossification seems to have been due to a separation of a few fibres of the rectus tendon freeing osteoblasts from the top of the patella. As has been remarked, there was definite evidence of old blood effusion outside the synovial membrane, which points to a considerable local trauma.

In conclusion, I have to thank Lieut.-Colonel R. J. C. Thompson, C.M.G., D.S.O., the officer commanding No. 14 General Hospital, for permission to publish this case.

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A CASE OF PROGRESSIVE MYOSITIS OSSIFICANS.

By J. W. GEARY GRANT, Cardiff.

M. W., a girl, age 4, was brought to the out-patient department of King Edward VII Hospital in the summer of 1917 for pain and stiffness in the back and shoulders. On examination there were found present large irregular plates of bone situated in various tendons of the erector spinæ muscles and in the latissimus dorsi, pectoralis major, and teres major. The arms were adducted to about 15 or 20 degrees from the chest and firmly fixed in that position. The scapulæ were also fixed to the chest wall. The condition appeared to be confined entirely to the muscles of the back and to the pectoro-axillary muscles. The actual condition is very well shown in the accompanying *x*-ray prints (*Figs.* 150, 151). Also, the child presented a peculiar deformity of the thumbs and great toes, caused by the absence of the proximal phalanges. This condition is also shown in the accompanying radiogram (*Fig.* 152). Beyond this there was no abnormality present, and the child appeared in fairly good health, although peevish and fretful. The picture was very typical of myositis ossificans progressiva. This condition is rare. In Osler's *System of Medicine* there are said to be 100 reported cases. Myositis ossificans traumatica is a fairly common condition, and differs entirely from that under consideration in the fact that it is a localized process affecting the muscles at their origin or insertion, and follows a definite trauma which may be a blow, a strain, or some chronic irritation, as in rider's bone of the adductor longus, or affecting the brachialis in injuries about the elbow-joint and the quadriceps similarly after injury.

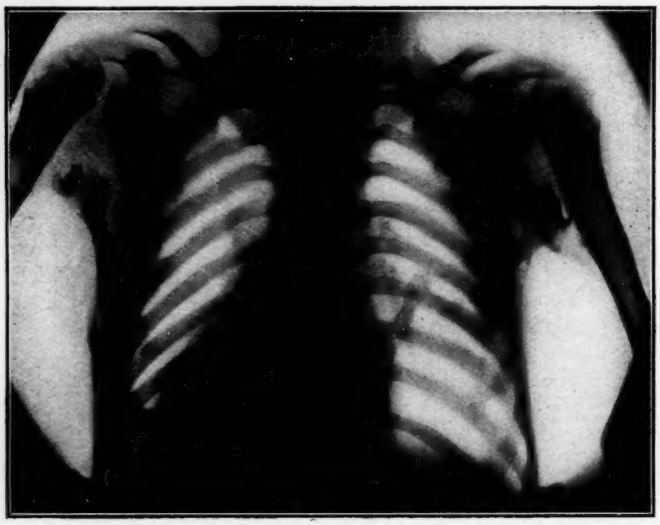

Fig. 150.

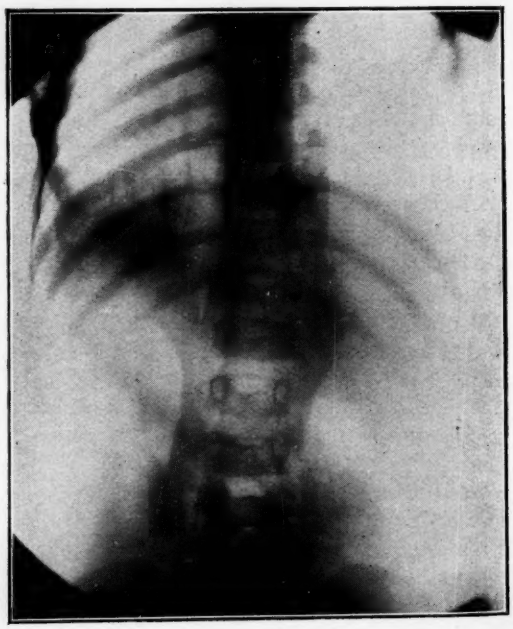

Fig. 151.

Idiopathic myositis ossificans was first described by Freke in 1740, and in 1898 Lorenz had collected 51 cases. The causation has been ascribed: (1) To an ossifying diathesis; (2) To cold; (3) To trauma; (4) To a process analogous to new growth (Ziegler); and (5) To a tropho-neurosis similar to progressive muscular atrophy (Nicoladoni). Various other causes more or

less fanciful have been suggested for it, but Nicoladoni's appears to be the most probable, for, like progressive muscular atrophy and pseudo-hypertrophic paralysis, the condition appears to occur in families and to come on in early life. The fact that these cases are associated with the peculiar congenital deformity of the great toes and thumbs appears definite evidence of a congenital origin. Of the recorded cases, 75 per cent have shown this deformity of the great toes and thumbs associated with absence of the first phalanges and a malformation of the heads of the metatarsals, well shown in the accompanying radiogram (*Fig.* 152), and it is quite probable that in the remaining 25 per cent of cases this condition may have escaped notice. It is, however, stated that the first phalanx is not absent, but is fused with the distal phalanx.

In a typical case the onset is insidious. There is first noted pain, and later a firm doughy swelling in the affected muscles. There may also be œdema and redness of the overlying skin. These symptoms subside in a few days, but the muscle remains firm, hard, and swollen. Some of these swellings are said to disappear, but the others undergo ossification in the course of two to eight months. In many of the cases, as in the one above described, the scapulæ are united to the chest wall by the bony growth. As the condition advances, the arms become flexed and fixed by ossification of the biceps and brachialis. The hips are fixed by ossification of the glutei, and the gait becomes precipitate. In some cases the muscles of the jaws become affected ; but the muscles of the eye, tongue, face, heart, diaphragm, perineum, and the sphincters are never found to suffer. The forearms and legs, the hands and the feet, are rarely affected by ossification. The pathology is obscure. In the early stage there is said to be a proliferation of embryonic tissue between the muscular fibres which undergoes organization into adult connective tissue, and this organization is accompanied by a fatty, waxy, and granular degeneration of muscle fibres and proliferation of the sarcolemma cells. Later, cartilage cells with a capsule appear in the fibrous mass, which ultimately undergoes development into true bone. By some it is stated that the condition is a primary parenchymatous inflammation ; degeneration of the muscle cell and the infiltration of small round cells is secondary to this. In the present case, in view of the greatly impaired movements of the arms, I determined to try the effect of removal of portions of the pectoralis major and latissimus dorsi muscles. I operated first on the left side, and removed large irregular plates of bone which were situated in the pectoralis major, the latissimus dorsi, and the teres major muscles. These plates appeared to consist of perfectly normal bone, and they were difficult to distinguish from the body of the scapula, to which the posterior ones were closely attached. The arms were then fixed in abduction. Unfortunately, for some unknown reason, in the course of a few days the wound suppurated. An autogenous vaccine was administered. The report on the pus was streptococcus in pure culture. The operation was performed on February 16. The wound healed up within a few weeks, and I then operated on the right side, and similar plates of bone were removed here. These had to be chiselled off the

FIG. 152.

edges of the bicipital groove, and from the axillary border of the scapula. The wound was closed and drained, and healed by first intention. The arms were then fixed at a right angle in a plaster corset. When seen some months after the operation, the plates of bone were completely re-formed in the anterior and posterior axillary folds, but the arms were well abducted beyond an angle of 45°, and were in a much more useful position. At the same time I may frankly say that I do not think the operation is worth doing. In every recorded case excision of the bony masses has been followed by recurrence. The condition unfortunately appears to be unamenable to any known form of treatment. In this case, so far it remains *in statu quo*.

I have operated upon several cases of myositis ossificans traumatica, in one of which there was a large plate of bone in the vastus externus, and in another there were irregular pipe-like stems of bone lying on the junction of the vastus internus and the crureus. In neither of these cases, as far as I was able to observe, was there any recurrence of the growth, and the functional result was excellent ; but the prognosis in myositis ossificans progressiva is totally different, whatever its pathology and etiology may prove to be. The disease occurs four times as frequently in males as in females.

A CASE OF ARTERIO-VENOUS ANEURYSM OF THE LEFT COMMON CAROTID ARTERY AND INTERNAL JUGULAR VEIN.

By H. S. FORSDIKE, London.

The patient, Pte. D. Y., age 26, had been employed as a warehouseman. He was wounded by shrapnel whilst loading a waggon ; after an interval, he fell and became unconscious. He recovered consciousness in a casualty clearing station some time the same night. Had been bleeding somewhat profusely.

Aug. 17.—Gunshot wound left side of neck. Expectorating blood-stained mucus. Loud systolic and diastolic hum over the left submaxillary triangle. *Aug.* 21.—Thrill and hum subsiding in intensity and area ; general condition good. *Aug.* 29.—Left temporal pulse much weaker than the right ; some loss of power in the right hand. *Aug.* 31.—Left temporal pulse imperceptible. Tumour seemed harder.

Sept. 7.—Patient was admitted into the Mile End Military Hospital ; he was a well-developed and well-nourished man, with only one eye.

A pulsating tumour is present on the left side of the neck in the line of the carotid, extending from the level of the cricoid cartilage to the angle of the jaw, and outwards from the larynx under cover of the sternomastoid. There is a healed scar at the lower part of the outer aspect of the tumour. On palpation, there is a marked thrill over the whole of the tumour ; on compressing the carotid below, the thrill disappears and the tumour collapses. On auscultation, a loud humming murmur is heard widely over the anterior triangle. Left temporal pulse just perceptible. Voice hoarse, and cough brassy. Right arm weak in muscular power ; reflexes + ; leg normal ; no increase of tendon-jerks. Face normal. He first noticed the weakness of the arm on the third or fourth day after the injury, because he could not hold a spoon steadily in the right hand. Left recurrent laryngeal involved, and vocal cord immobile. No evidence of sympathetic involvement. *X*-ray shows the presence of a piece of metal at the site of the swelling in the neck.

Sept. 12.—The tumour has increased considerably in the last twenty-four hours, but is firmer in the upper and outer part, and the thrill is now only felt in the lower part. Owing to rapid increase in the size of the tumour, operative treatment was decided upon after consultation with Sir Hugh Rigby.

Operation, *Sept.* 16.—With the aid of Sir Hugh Rigby, who kindly assisted me, an incision was made over the tumour along the anterior border of the sternomastoid,

extending from the lobule of the ear to below the cricoid cartilage. The sternomastoid was found stretched over the tumour ; it was divided transversely. The common carotid artery was exposed at the lower end of the wound and a temporary clamp applied. The sac was then gradually separated from the surrounding structures and, being very thin, was opened at one spot accidentally ; through this opening a smart hæmorrhage took place. The internal and external carotids and the jugular vein were next exposed in the upper part of the wound ; they were ligatured as close to the sac as possible and divided. A large common facial vein was divided between two ligatures. The sac was then freed by dissection posteriorly, exposing the vagus, and removed intact. Whilst *in situ* a foreign body could be felt in the sac. There was considerable venous hæmorrhage during the operation. The wound was then closed and drained for forty-eight hours.

Sept. 17.—The patient is somewhat drowsy, but answers questions slowly. *Sept.* 18.—Wound dressed and tube removed. There is marked weakness of the left side of the face involving the whole distribution of the facial nerve. There is also marked weakness of the left hand, with partial wrist-drop.

Mental Condition.—The patient replies to any simple question briskly, and answers correctly simple arithmetical questions ; but reads his paper upside-down.

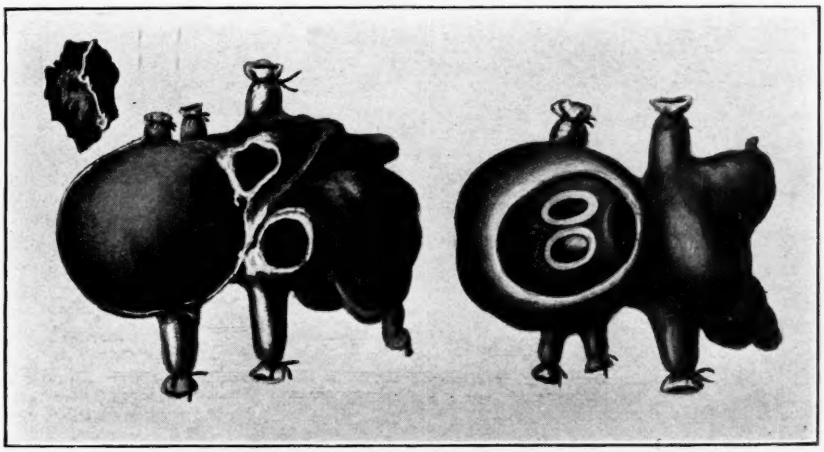

FIG. 153.—Anterior view of specimen on left, posterior on right. The missile is also shown. See text.

Sept. 22.—Patient's general condition appears quite satisfactory. The temperature and pulse are normal ; the wound looks healthy ; the facial palsy is much improved ; the voice seems clearer. *Sept.* 23.—Does not answer questions ; the right hand does not move ; right leg is spastic ; knee-jerks are increased ; ankle-clonus present. *Sept.* 24.—He became comatose in the night, and died on Sept. 25.

Post Mortem.—Wound healed. The veins on the surface of the left hemisphere of the brain are much engorged. The middle cerebral artery is found to be thrombosed. The brain tissue is soft, notably in the region of the internal capsule, which is of the consistency of jelly. There is no excess of fluid in the ventricles.

Specimen.—The specimen removed by operation consists of a portion of the common carotid artery and its two main branches, and a portion of the internal jugular vein (*Fig.* 153). There is a double sac present, one connected with the vein and another with the artery. There is a large communicating opening between the two sacs, oval in shape, with smooth edges. Viewed anteriorly, the venous dilatation shows two openings in its wall : the upper one is the common facial vein divided close to the sac wall, and the lower is the opening caused by the entry of the missile. The anterior surface of this sac lay beneath, and was closely adherent to, the sternomastoid muscle, fibres of which were removed with the specimen.

On opening the arterial sac from behind, the artery was found to have been cleanly severed in a transverse direction by the missile, and the everted smooth edges of the intima are clearly shown in the illustration. The opening from the vein to the artery can be seen just to the right of the divided ends of the vessel. The missile was found in the arterial sac after removal of the latter.

Remarks.—Operative treatment in this case appeared to be clearly indicated owing to the rapid increase in the size of the aneurysm for two days previous to operation. Arterial or venous suture had been contemplated, but the conditions found on exposure of the vessels, and the difficulty of controlling hæmorrhage, made ligature of the main vessels inevitable. The arterial sac extended medially behind the thyroid cartilage, and the venous sac extended outwards beneath the sternomastoid muscle. The surrounding parts were closely adherent, and this rendered dissection difficult.

On viewing the severed artery from behind, it would appear that circular arterial suture might have been attempted, but owing to the difficulties encountered, ligation was considered to be the wiser course.

The transient monoplegia of the right arm, noticed after the initial injury, had quite recovered before the operation, and it was hoped that the interval of four weeks would have been a sufficient time to ensure recovery of the collateral circulation.

RECOVERY IN GUNSHOT WOUNDS OF THE ABDOMEN PRODUCED BY LARGE FRAGMENTS OF METAL.

By Major GORDON TAYLOR, R.A.M.C., London.

I have a conviction that a man hit in the abdomen by a really large fragment of shell or bomb practically never recovers. The largest piece which I have removed from a man who made a good recovery weighed just under three ounces (*Fig.* 154). This particular case is remarkable, both in the size of the missile, and also in the severity of the injuries which the wounded man survived.

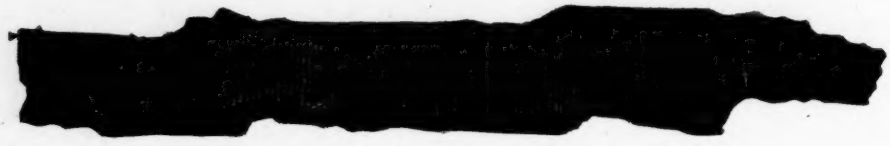

Fig. 154.—Missile from Major Gordon Taylor's case. Natural size.

Penetrating wound of the abdomen; hernia of the small bowel; wound of the bladder; fracture of rib, anterior portion of iliac crest, and pubic bone; double resection of the bowel; recovery.

Pte. T. was admitted into a casualty clearing station on Sept. 18, 1918, with a severe wound of the abdomen. He came to operation eight and a half hours after being hit, and was found to have a hernia of shattered, strangled small intestine through a wound in the right hypochondrium; about 18 inches of bowel were thus prolapsed. The missile had then passed down between the internal oblique and transversalis muscles of the abdominal wall on the right side, and had struck against and shattered the anterior part of the crest of the ilium. Thence its course was deflected again into the peritoneal cavity, and it had become impacted in the posterior surface of the right pubic bone, transfixing the bladder and impaling a coil of ileum against that bone. With such force had the projectile been driven into the os pubis, that a considerable pull was required to dislodge it. The patient, when placed upon the operating table, had a surprisingly good pulse of 96; but immediately the wound of entry was enlarged and the constriction of the neck of the prolapsed bowel thereby released, the pulse-rate rose to 130. The wound

was filthy, and parietes and bowel alike were covered with grease and dirt. Four feet of badly damaged and perforated jejunum were resected, and the other coils of jejunum and upper ileum were assiduously cleansed of grease and clothing. The coil of lower ileum impaled against the pubic bone was gangrenous and stinking, and a second resection of 2½ feet was performed. The posterior wall of the bladder was sutured, and a glove drain was passed down into the cave of Retzius towards the wound on the anterior vesical surface. Very wide excision of the damaged abdominal muscles was performed, after the peritoneum had been closed; a defect in the latter was filled in by a graft of fascia obtained from the anterior layer of the sheath of the rectus. The anterior end of the crest of the ilium was widely exsected, the wound was packed with gauze soaked in flavine, and frequent instillations with flavine through Carrel's tubes were enjoined. Nine hundred cubic centimetres of blood were transfused by Captain Purce, and the patient was treated by the usual resuscitatory measures. The gauze and Carrel's tubes were removed on the fifth day, and the skin wound was sutured. The patient was evacuated to the base on the fourteenth day, and subsequently to England. He was convalescent on Feb. 7, 1919.

This case is of interest for two reasons: first, as a successful double intestinal resection, complicated by other desperate injuries; and next, the patient is the fortunate survivor of an injury to the interior of the belly produced by a missile weighing nearly three ounces.

Major Charles, of 30 Casualty Clearing Station and Ipswich, a very experienced abdominal surgeon in France, has kindly lent me a photograph (*Fig.* 155) showing the largest piece of shell which he had removed from the belly. This man was wounded in the cæcum, but died on the third day from gas infection of the retroperitoneal space.

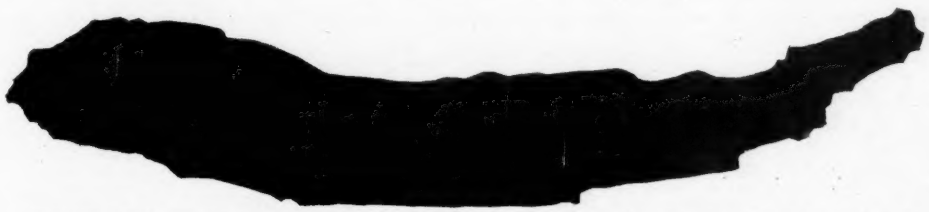

FIG. 155.—Major Charles's case. The largest piece of metal ever removed by him from the abdominal cavity. The missile entered through the buttock and was found lying loose in the abdominal cavity, having perforated the cæcum. Patient died the third day from gas infection of the retroperitoneal space. Post-mortem—no marked peritonitis.

Major Worthington, of 54 Casualty Clearing Station and Lowestoft, has courteously given me notes of a case where he removed a fragment of shell weighing just over half a pound. The patient was admitted into the casualty clearing station in fair condition, with a pulse of 100, although he had been wounded eleven hours previously. The wound of entry was large and dirty, and situated in the left umbilical region. A large foreign body was found lying loose in the pelvis and removed; the ileum was sutured in two places, the sigmoid in one, the pelvic colon in one; fat grafts were applied over the rents in the large intestine. The patient was sent to the base three weeks after the injury, his evacuation having been delayed through massive collapse of the lung.

Major Saint, of 50 Casualty Clearing Station and Newcastle-on-Tyne, had a successful abdomino-thoracic case, where a fragment of shell weighing two ounces had traversed the diaphragm and liver, and produced two perforations in the duodenum and one in the hepatic flexure of the colon.

I am aware of two cases where the patient had been struck by the nose-cap of a shell. In one of these cases, under the care of Colonel Gask, the missile had passed from left to right, damaging the bowel, and lodging in Scarpa's triangle of the right side. Major Tudor Edwards met with a case where a nose-cap entered Scarpa's triangle on the left side and, ploughing up the lower abdominal parietes, penetrated the abdominal cavity. Both these cases resulted fatally.

The injuries produced inside the abdomen by really large fragments of metal are almost irrecoverable.

REVIEWS AND NOTICES OF BOOKS.

Chest Radiography at a Casualty Clearing Station: with Atlas. By R. LINDSAY REA, B.Sc., M.B., late Supervising *X*-ray Officer 4th Army B.E.F. Quarto. Pp. viii + 24; and Atlas, with 61 illustrations. 1919. London: H. K. Lewis & Co. 15s. net.

THIS book consists of three chapters dealing with the constitution of an *x*-ray department of a casualty clearing station and the methods employed in examining chest injuries, and an atlas of chest radiograms.

The book is written by a man with much practical experience of *x*-ray work in the 'field,' and was intended to help beginners and those to whom chest work particularly was new. The first chapter gives hints in the methods of housing and fitting up the department, and the two succeeding chapters are devoted to the more technical details concerning the examination and diagnosis of the various injuries met with in battle wounds of the chest.

Luckily the need for this book has largely disappeared, though it is a happy thing that the many excellent radiograms included in the Atlas should be put on record. *X* rays in the 'field' were a novelty, and much had to be learnt as to the best type of apparatus to be employed, together with the necessary transport and housing. As the author states, the *x*-ray departments were often out of action, and failed the surgeon during the war of movement, for the reason that no provision was made for transport and housing. Unfortunately, he himself provides no clear-cut scheme to help the administrator of the future to solve these problems. It might also be suggested that the book would not suffer at all by being considerably condensed, and arranged more systematically, in order to be of service in the future to men going on active service.

Genito-urinary Diseases and Syphilis. By HENRY H. MORTON, M.D., F.R.C.S. Fourth edition. Pp. 807, with 330 illustrations and 36 coloured plates. 1918. London: Henry Kimpton. 36s. net.

IT is not an easy task to compress such a large subject as genito-urinary diseases and syphilis into one volume, and the rapid advances which have been made in this department must have rendered it particularly difficult to keep such a work up to date. For the most part this admirably illustrated edition of Dr. Morton's work is a mine of useful information, displayed in a manner which makes for easy comprehension and remembrance. It bears signs, however, of hasty revision, which has resulted in some unnecessary duplication, omission of important points, and faulty arrangement.

Probably the commonest cause of turbid urine is acute gonorrhœa, yet in the first chapter, which deals with the investigation of this condition, the author directs us to explore the urethra with a bulbous bougie, without any warning not to do so if the urethra is acutely inflamed.

In the section dealing with the diagnosis of balanitis when the prepuce cannot be retracted, reliance is placed on the microscopical exclusion of gonococci. Such a course imposes a heavy task on the microscopist, and, in any event, is one which is certain to lead to the missing of an early chancre. In the section on the diagnosis of chancroid in cases of phimosis, there is the same reluctance to expose the glans by operation. Even when the discharge is bloody and foul-smelling, one is recommended to put the patient on iodides and wait events in order to decide the question of syphilis. In these days, when we know how much depends on an early diagnosis of syphilis, we should have thought simple slitting of the prepuce of no moment, even if *Spirochæta pallida* could not be found in the preputial discharge.

The diagnosis of gumma from carcinoma of the penis appears to require further revision. We read that the question of gumma would be settled by a few weeks' treatment with mercury and iodide, and that the blood would show a positive Wassermann. Apart from the fact that '606' would afford a quicker therapeutic test, it would appear safer to say that, in carcinoma, "the blood *might* assist by showing a negative reaction," since it is well enough known that syphilis does not exclude cancer.

The method of staining by Gram described on page 139 would be improved by imposing a strict time limit on the carbol-fuchsin counter-stain. Many errors are made by the over-use of this powerful stain, Gram-positive organisms then appearing Gram-negative. The descriptions of dark-ground microscopy which appear on pages 651 and 721 are too meagre to be of practical value. Incidentally, the device placed inside the oil-immersion objective for dark-ground work is a stop, not a condenser.

The diagnosis of scrotal swellings is an important section, and might usefully be more detailed. We think, also, that three months' observation of a case of chancroid rather than three or four weeks, as recommended, would be less likely to miss cases of mixed syphilis and chancroid. The recommendation in cases of phagedæna to watch the effect of a vigorous course of antisyphilitic treatment seems hardly in accordance with modern practice. The author rightly condemns the use of astringents in early gonorrhœa, but his recommendation to use 1–1000 potassium permanganate seems inconsistent with this view, even though only one irrigation of this strength is given. Also, the raising of an irrigator to a height of 9 ft. above the floor (7ft. 4 in. above the penis) seems likely to result in much epididymitis.

In the section on syphilis some space might have been saved by describing the histology of a chancre once rather than twice within fifteen pages. Another instance of unnecessary repetition occurs on pages 42 and 435, where Geraghty's description of the phenolsulphonephthalein test is duplicated word for word.

Generally speaking, the section on arsenobenzol treatment is too superficial to be of practical value. The contents of an ampoule of salvarsan are not 0·06 grm. as mentioned on page 752, and it is of little use to be told to alkalize with 23 drops of sodium hydroxide solution when the strength of the solution is not mentioned. Dermatitis is described as a Herxheimer reaction, and 'nitroid' crises as anaphylaxis, both of them statements which are open to considerable doubt. There is no mention of jaundice as a toxic effect of arsenobenzol treatment, and too little is said as to the precautions to be taken to avoid toxic effects generally.

Amongst minor defects probably the result of hasty preparation, are *Spirochætæ pallidum* on page 640, and *Spirochætæ pallida* on various pages, while on page 497 the word 'colon' is used to indicate *B. coli communis*.

We offer these small criticisms in a spirit of helpfulness and the hope that some of them may prove useful to the author in the preparation of his next edition.

Pensions and the Principles of their Evaluation. By Ll. Jones Llewellyn, M.B., and A. Bassett Jones, M.B. Large 8vo. Pp. 702 + xxvii. 1919. London: Wm. Heinemann. 30s. net.

The title of this work is hardly likely in itself to prove very attractive to the ordinary medical reader; but those who, knowing that the names of the authors are a guarantee of excellence, glance at the book, will soon find themselves deeply interested, whilst to those who are concerned with the evaluation of disabilities and infirmities it will prove of the greatest practical help. Throughout the work the authors have succeeded in bringing forward their subject in a most attractive manner, and incidentally we note that in the historical survey of the subject of pensions they deal with all the main advances between the reign of Darius (521–485 B.C.) and the present time.

A very valuable section deals with the mode of procedure in the examination of claims for pensions, and discusses the whole subject of malingering and the simulation of disabilities and infirmities, the origin of the disability in question, and adaptation in relation to disabilities.

In dealing with the principles upon which the evaluation of injuries is based, the professional as opposed to the purely physiological aspect of the question is fully considered, and a clear statement is given of the reasons for assessing compensation on the basis of loss or depreciation of functional capacity rather than on the basis of anatomical loss. In summarizing their conclusions on the principles of evaluation, the authors express the opinion that these principles are in urgent need of definition, and they suggest that a schedule should be drawn up by a council of experts on the lines of the *Guide Barème des Invalidités* issued by the French Ministry of War.

After dealing with the general aspects of the subject, the authors proceed to a full consideration of all the more important injuries, such as fractures, ankyloses, injuries to nerves, amputations, etc., in their relation to pensions, and the book ends with a very helpful chapter by Mr. W. M. Beaumont on "Evaluation in relation to the Eye."

Altogether we feel that we cannot praise too highly this very important work, and we confidently recommend it to the careful study of the Profession.

Intravenous Injection in Wound Shock: the Oliver-Sharkey Lectures delivered before the Royal College of Physicians in May, 1918. By W. M. Bayliss, M.A. Large 8vo. Pp. 172 + xi, illustrated. London: Longmans, Green & Co. 9s. net.

As the authoritative exposition of a new method of treatment, the value of which is widely accepted, this book must already rank as a classic. The author is in the front rank of British physiologists, and his position on the Shock Committee of the Medical Research Committee has given him a strategic position. The book contains an account of the failure of other chemical substances used for intravenous injection, sets forth the virtues of gum acacia and the method of using it, and briefly reviews the present-day conception of surgical shock. One would have liked

a fuller exposition of this difficult and interesting subject. Whether Professor Bayliss's gum infusion, or blood transfusion, or some other method yet to come, is to be the effectual remedy for conditions of hæmorrhage, shock, and the like, it is for the future to show. One feels, personally, that the good may be the enemy of the best, and that, difficult as it may be to find the donors, the time, and the apparatus for blood transfusion, yet theoretically, and probably in practice also, the proper thing to fill the circulatory system with is its native fluid, and it will be a pity if what we have learned about the technique for this procedure is forgotten because it is easier to give gum.

Roentgen Diagnosis of Diseases of the Head. By Dr. ARTHUR SCHULLER, Vienna. Translated by F. F. Stocking, M.D. Large 8vo. Pp. 305, with 97 illustrations. 1918. London: Henry Kimpton. 21s. net.

THIS book deals with a fascinating subject—skiagraphy of the skull, and the interpretation of the various changes that may be observed. It is based on a very extensive experience, and contains a mass of detail. But it is essentially German—heavy reading, profuse in references, and with a bibliography of 34 pages. The present-day student requires a work with the stamp of individuality, and a book which deals clearly and concisely with the subject concerned. Only an enthusiast could wade through this work from beginning to end with any mastery of the detail; such a task is far too laborious. The volume, however, has its use in bringing forward many facts useful in the Roentgen diagnosis of diseases of the head, and for general reference.

The author makes no allusion to stereoscopic radiography—an essential feature in so many cases—and injuries of the skull are dismissed in six pages.

The work is divided into two main sections. The first deals with anomalies in shape and size in consequence of disturbances in development, and anomalies in the structure of the skull due to inflammation, atrophy, hypertrophy, tumours, and fractures. The second section is concerned with the Roentgen diagnosis of intracranial diseases.

SHORT NOTES ON BOOKS.

Elements of Surgical Diagnosis. By SIR ALFRED PEARCE GOULD and ERIC PEARCE GOULD. Fifth edition. Pp. 722 and 16 radiographic plates. London: Cassell & Co. 12s. 6d.

WE warmly welcome this new edition of a most valuable manual by one of the greatest masters of surgical diagnosis, aided by his son. It is needless to describe it in detail, because it is so well known to all English readers. Although it is the type of book read chiefly by students, yet more mature practitioners would do well sometimes to re-read its pages in order that they might once more get a stimulus to careful thinking about both diagnosis of disease and the systematic teaching of this most difficult subject. In the present edition new sections appear on gas gangrene and causalgia, and there are many new *x*-ray pictures.

Technic of the Carrel Method. By J. DUMAS and ANNE CARREL. Authorized translation by ADRIAN V. S. LAMBERT, with an introduction by W. W. KEEN. Pp. 90, with illustrations. London: Heinemann. 6s.

THIS is a very useful practical description of the details which have proved most important in the successful carrying out of Carrel's method of disinfecting septic wounds, and we look forward to an account of the application of this system to the septic wounds of civil surgery, where we feel sure it has a great future.

Lewis's Medical and Scientific Library. New edition, revised to the end of 1917. Pp. 492. London: H. K. Lewis & Co. 12s. 6d.

THIS classified book list is so arranged as to form a convenient guide to works of reference on any medical subject, and as such will be most useful, especially to those who are at a distance from large libraries, but who can obtain the loan of the books catalogued, through the post.